EDDY'S EXPERIMENTAL PHYSIOLOGY & ANATOMY

REVISED EDITION

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EXPERIMENTAL PHYSIOLOGY AND ANATOMY

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W. P. 4

PREFACE

THOUGH the importance of Physiology in secondary schools is everywhere recognized, little attempt has been made to place the subject on an experimental basis. The recent great advances in physiological chemistry have directed the attention to the possibilities of the experimental method as a means of investigating the principles of the subject. This book represents a selection of experimental matter which is adapted to the age of elementary students of the subject and which, at the same time, will present the facts of physiology in a concrete form.

The starred topics in the following table of contents constitute a brief course covering that which is most essential; and the optional exercises make it possible to extend the work at the discretion of the teacher.[1] The ingenuity of the teacher will readily suggest substitutes for the material suggested when the laboratory facilities of the school are inadequate.

Some of the exercises may be made demonstrations, and time in school may be saved by assigning some of the simpler exercises as part of the home work of the pupil.

In the present edition several changes have been made, based partly on experience gained in teaching the first edition and partly on the advance in scientific knowledge of the

[1] The book in its starred topics meets the requirements of the New York State Syllabus, and as a whole has been accepted by the Harvard College authorities as meeting the entrance requirements of that Institution.

subject. It has been found, for example, that certain phases of elementary chemistry need emphasis for proper appreciation of later phases of pure physiology. To that end, exercises on chemical and physical change, and on mixtures and solutions have been introduced. Again, new reagents have been devised to facilitate various tests; for example, the Benedict solution in place of the less stable Fehling's solution, and the biuret reagent, which does away with the complicated procedure for the biuret test for protein. The collodion bag dialyzer is another laboratory device which has simplified the teaching of osmosis and has accelerated the process so that with it osmotic pressures may be obtained in twenty minutes that formerly required some hours. The wording of many experiments has been altered and the procedure shortened and simplified to enable the principle to be more readily grasped. For example, in the digestion experiments the work has been rearranged in such a way as to separate the determination of the conditions for digestion from the mere process of digestion and thus permit the pupil to reach the conclusions separately and with added emphasis and clarity. The recent changes in our views as to the nature of fat digestion and the action of bile are also developed in new forms of experiment, and this change typifies another form of improvement in the present edition.

I wish to acknowledge again the many helpful suggestions given me by my colleagues of the High School of Commerce and by others in various parts of the country who have called my attention to faults in the earlier edition. To Dr. E. A. Darling of Harvard College and to Mr. Frank O. Payne of the High School of Commerce I am especially indebted for their aid and critical review of the manuscript of the first edition. Many of the improvements in methods and laboratory devices I owe directly to my association with and to

suggestions from Professor William J. Gies of the Columbia University Department of Biological Chemistry, notably the collodion bag dialyzer and the biuret reagent. To Dr. Stanley R. Benedict I beg to give credit for the solution which bears his name. To Mr. C. W. Hahn, my colleague in the High School of Commerce, I am also indebted for valuable suggestions based upon teaching experiments with the first edition. Finally, I wish to acknowledge my debt to my wife for assistance in many details of grammatical arrangement and mechanical labor involved in the work.

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METHOD OF EXPERIMENT

It has been my purpose so to state each of the following exercises as to admit of its performance by the pupil with a minimum amount of direction from the teacher. Most of the exercises should be thus performed by each pupil individually, or by two pupils together; but of course the teacher may select as many as desired for performance as demonstrations before the class.

It is essential that each pupil make a suitable record of all exercises performed, in a carefully prepared notebook. It is recommended that a separate-leaf notebook be used for this purpose, as this makes possible the inspection of one set of exercises without handling the entire books, and permits the rewriting of unsatisfactory work without disturbing the arrangement of the book.

It is generally agreed, too, that the book should consist of original reports made at the time of experiment, and not of matter copied from original rough drafts.

Frequent examination of all laboratory notes by the teacher is also essential to good work, and the proper status of the notebook work can be secured only by giving it a definite proportion in the marking of the pupil's work. A rubber stamp with the word "Approved" and the instructor's name may be obtained of any stationer at small expense and will greatly facilitate the work of correction. Neatness as well as accuracy and adequacy of report should receive proper weight in the marking of notebook work.

When the work is completed the student should prepare an index of drawings, records of experiments, and descriptions of demonstrations contained in the notebook. It is well to indicate in this index, after each title, whether the work was done by the pupil or observed and recorded by him, and whether in the laboratory or as home work.

The following directions may prove of value as indicating a satisfactory method of arrangement of a notebook record:

A. Record the number and date of the exercise.

B. Make drawings of the apparatus used, when necessary, and label them properly.

C. State as briefly as possible:

(1) What was done.

(2) What happened as the result of (1).

(3) What meaning these results have, and the purpose of the exercise.

D. Answer all questions in the text and try to condense your statements into as concise and brief a form as possible.

The exercises as a rule should precede the text study and serve as a basis for such study.

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Required topics are indicated by a star (*); the others are optional.

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Excretion

Nervous System

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Bacteria

EXPERIMENTAL PHYSIOLOGY AND ANATOMY

PRELIMINARY EXERCISES

I. — Glass Bending and Cutting (Optional)

Apparatus. — Several pieces of quarter-inch glass tubing about two feet in length, a three-cornered file, a Bunsen burner with fishtail attachment.

Directions. — *A. Bending.* Place the fishtail attachment on the burner and light the gas. Hold at the ends the tube which is to be bent and bring into the flame the

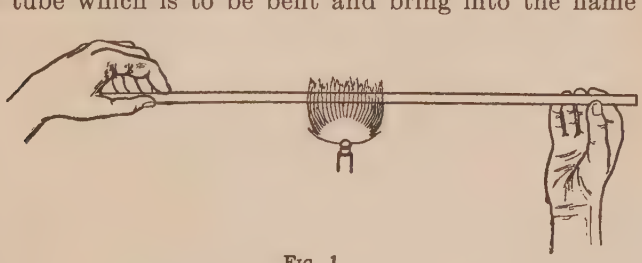

Fig. 1.

part at which you wish the bend (see Fig. 1). Turn the tube constantly to insure equal heating of all parts, and when the glass is flexible remove from the flame and bend the two ends slowly toward each other until the desired angle is obtained. Use care to keep the two ends in the same plane, and do not bend quickly, as that would cause

buckling. If the glass cools too soon return it to the flame and treat as before.

B. Cutting. Wet the file and, holding the tube firmly with finger and thumb, make a slight scratch across it. Turn the tube over and repeat the operation at a point directly opposite. Now grasp the tube in both hands, one on each side of the scratches, and bend sharply. The result should be a clean, square-ended break. The edges may be rounded by holding them in the flame a moment.

II. — Collection of Gases (Optional)

Apparatus. — Pneumatic trough and support, glass tube bent at right angles, large-mouthed bottles, piece of glass to cover mouth of bottle.

Directions. — *A.* Fill the trough with water to the depth of a half inch above the top of the support. Fill the bottle with water, cover the mouth with the glass, and invert, putting the mouth under the water of the trough. Remove the piece of glass, and place the bottle over one of the holes of the support. Does the water flow out? Explain.

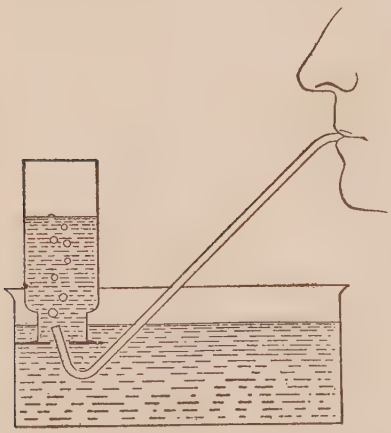

Fig. 2.

Now introduce the short end of the glass tube into the mouth of the bottle (see Fig. 2) and blow

through the other end. Where does this gas go? Why? Would this method of collecting gases be successful if they were readily soluble in water?

B. Fill a second bottle with water and invert in the same way as the first. Bring the one containing the gas under

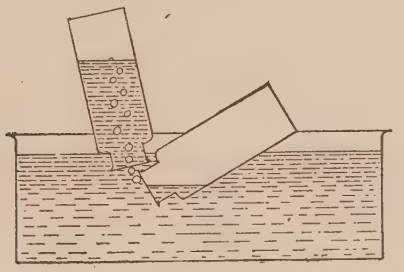

FIG. 3.

the one containing the water, and gradually turn it mouth upward (see Fig. 3). In this way gases may be transferred from one vessel to another for study.

INTRODUCTORY EXERCISES IN PHYSICS AND CHEMISTRY

III. — Chemical Change (Optional)

Apparatus. — Powdered sulphur, test tube, strip of copper foil, Bunsen burner.

Directions. — Examine the sulphur and copper foil carefully and write a description of each, stating the characteristic features of each substance.

Next, place a strip of copper foil an inch long in the test tube and cover to the depth of a quarter inch with powdered sulphur. Heat the tube in the flame of the lamp and note every change that takes place. State the changes that take place in the sulphur in the order of their occurrence. State what happens to the copper. When no further change occurs, remove the strip from the tube and examine it carefully. Does it bend easily? Is it the color of copper? Can you find any sulphur? Is the strip copper? Sulphur? Give reasons for your statement. Changes that result in a new substance with new properties are called chemical changes. Write a statement giving your opinion as to whether this was a chemical change and include in this statement your reasons for your conclusion.

IV. — Physical Change (Optional)

Apparatus. — Ice, chemical thermometer, beaker, tripod, Bunsen burner.

Directions. — Place several pieces of ice in the beaker and stir it about with the thermometer. Note the tempera-

ture of the ice. Next, light the burner and heat the ice gently. What happens to the ice? Does the temperature rise? Was this change in the ice like that of the sulphur or copper? Reason for your answer.

Continue the heating until the temperature rises no further. What is the reading at this point? What change is taking place? Is it a chemical change? Reasons for answer.

Write a statement comparing the changes observed in Exercises III and IV and explain the differences between them.

V. — Mixtures and Solutions (Optional)

Apparatus. — Powdered chalk, table salt, water, 4 beakers, 2 funnels, filter paper, 2 evaporating dishes, 2 Bunsen burners.

Directions. — *A*. Fill a beaker half full of water and stir into it a teaspoonful of powdered chalk. What appearance has the water? Fit a filter paper into a funnel and pour half of the chalk and water mixture through the filter into the second beaker. Compare the filtered and unfiltered portions. Pour half the filtered portion into an evaporating dish and evaporate to dryness. Is any residue left in the dish?

B. Repeat the steps given in *A* with the rest of the apparatus, but substitute a teaspoonful of salt for the chalk. Record the results as in *A*.

C. Compare the results of *A* and *B* and from your comparison answer these questions: (*a*) Does chalk dissolve in water? (*b*) Does salt? (*c*) How can you demonstrate the solubility or insolubility of any substance?

VI. — Properties of Phosphorus

Apparatus. — Piece of yellow phosphorus, evaporating dish, forceps, knife.

Directions. — (Caution! Phosphorus should be kept under water and cut under water. It should not be allowed to come in contact with the bare skin.)

Fill the evaporating dish with water and with the forceps place the piece of phosphorus in it. With the knife cut off a piece and examine the cut surface. Does it cut easily? What color is the new cut surface? Leave this exposed to the light for a time, keeping it under water, and note any change in color. Is phosphorus soluble in water?

Pick up a piece with the forceps, wipe dry with filter or blotting paper, and hold in the air a moment. Describe what takes place. Why is phosphorus kept under water? Does phosphorus give off any odor?

Rub phosphorus gently on a piece of paper and examine the paper afterwards in the dark. What evidence have you that phosphorus burns at a low temperature?

(Bone and brain are the parts of the body richest in phosphorus.)

Make a list of the properties of phosphorus so far as you have observed them.

VII. — Properties of Sulphur

Apparatus. — Half a teaspoonful of flowers of sulphur or a piece of stick sulphur, a silver spoon, a hard-boiled egg, a raw egg, an evaporating dish, alcohol lamp or Bunsen burner.

Directions. — Examine a little of the sulphur. Describe its odor, taste, color. Shake some up in water. Does it dissolve?

Place a little in the dry evaporating dish and heat gently. Does it melt? Describe its condition. Continue to heat, and describe the various changes through which it passes.

Touch a match to a little dry sulphur. Does it burn? Describe the result. Smell of the fumes (Caution!). Where have you noticed this odor before? (This odor is due to a gas called *sulphur dioxide*, and this gas is formed whenever sulphur is burned.)

Place a little of the sulphur in the bowl of the silver spoon. After a moment brush it off. Is the silver still bright? (When silver is brought in contact with sulphur the latter unites with it and forms a compound called *silver sulphide*, which is black.)

Mince the hard-boiled egg with the handle of the silver spoon. What happens? Compare with above result. Eggs contain sulphur.

Place the raw egg in a clean evaporating dish and leave in a warm place for several days.[1] When the egg decays note the odor. (This odor is due to another compound of sulphur called *hydrogen sulphide*. When animal flesh decays it gives off this odor, showing that flesh contains sulphur.)

Mention seven properties of sulphur which you have observed in the above experiments.

VIII. — Properties of Carbon

Apparatus. — Stick of wood charcoal, bottle with a small mouth, limewater,[2] glass tube six or eight inches long, beaker, test tubes, splinter of wood, pieces of meat, piece of marble, hydrochloric acid.

[1] It is well to place the dish in a closed vessel containing a little water, as otherwise the egg may dry up without decaying,

[2] Limewater may be made by shaking a little quicklime in water, allowing the mixture to settle and decanting the clear liquid.

Directions. — Examine the charcoal stick. (Charcoal is one of the forms of carbon.) Describe its color, odor, taste. Does it dissolve in water?

Light the stick, after trimming it to such a size as to enable it to be thrust through the neck of the bottle. Does it give off any odor in burning? Is it like or unlike sulphur in this respect?

Thrust the lighted stick of charcoal into the bottle and keep it there until the flame goes out. Now remove it and cover the mouth of the bottle with the finger. Can you see anything in the bottle? Pour a little clear limewater into the bottle and shake the bottle. What happens to the color of the limewater? What sort of substance must be present in the bottle? (When carbon burns it forms a gaseous compound with the oxygen of the air called *carbon dioxide.* This gas is the only one that will cause the change in limewater noted above.)

Rinse out the bottle with water. Light the wood splinter and thrust into the bottle. Proceed as with the charcoal. Test the contents of the bottle with limewater. What evidence have you that wood contains carbon?

Burn the piece of meat by heating it in the test tube. Pour limewater into the tube. What evidence have you that animal flesh contains carbon?

Place the piece of marble in a clean test tube. Pour on it a little hydrochloric acid which has been diluted previously with twice its volume of water. What evidence of action have you? Suspend a drop of limewater in the mouth of the tube. Hydrochloric acid and water contain no carbon; what must you conclude as to the presence of carbon in the marble?

(Carbon is to be found in all animal and vegetable compounds and in some minerals.)

Pour some of the limewater into the beaker. By means of the glass tube blow some of your breath through the liquid in the beaker. In what form is the carbon in your breath? (Expired air contains about 4 parts of this gas in every 100 parts of the expired air. Ordinary air contains about .04 part of this gas in 100 parts, or about 4 parts in every 10,000 parts of air.)

(Besides charcoal, the other forms of carbon are diamond and graphite. All the forms of carbon are odorless, tasteless, and insoluble in water; and if strongly heated in the presence of oxygen, each form of carbon will combine with it and form carbon dioxide.)

IX. — Properties of Iron

Apparatus. — Several feet of fine wrought-iron wire, a magnet, an evaporating dish.

Directions. — Bring the magnet in contact with the iron. Raise the magnet. Note the result. See if other things act similarly toward the magnet.

Place a coil of the wire in a warm, dry place. Place a like coil in the evaporating dish and cover with water. Leave both coils for several days, and then examine them. Note any differences between the two coils. What conditions are favorable to this change? (Rust is a compound that iron forms with the oxygen of air and water. It is this power of iron to unite with oxygen that makes it valuable as a part of the blood in the animal body; see Exercise XLVI, last paragraph.)

X. — Oxygen and Oxidation

Apparatus. — Red oxide of mercury (mercuric oxide), test tube, stick of charcoal, limewater and glass tube, Bunsen burner.

Directions. — Place in a test tube as much red oxide as you can get on your finger nail. Heat the test tube in the

flame (see Fig. 4.)[1] Heat the end of the charcoal stick until it glows, and introduce it into the mouth of the test tube.

Fig. 4.

After heating the oxide hot you will notice a change in the glow of the charcoal. Describe it. Can you see anything in the tube? If it be a colorless gas that is acting on the charcoal can that gas be air? Reasons for your statement.

Remove the tube from the flame. When the stick ceases to glow remove it and substitute for it a drop of limewater on the end of the glass tube. What happens? What does this indicate? As the tube cools what do you see on the sides of the tube? Do you know the name of this substance?

Explanation. Oxide of mercury is a compound of mercury (quicksilver) and oxygen. Heat decomposes this into oxygen and mercury. In what form were these two substances given off in the above experiment? We have already learned that when charcoal burns it forms a gas called *carbon dioxide*. How was this gas formed in the above exercise? We can express the above actions in the form of equations as follows:

(1) Oxide of mercury = oxygen and mercury.

(2) Oxygen + carbon = oxide of carbon.

In chemical language the process illustrated in (1) is *analysis*, or the separation of a compound into its parts. The process illustrated in (2) is *synthesis*, or the union of parts to make a compound. All chemical actions may be grouped under one or the other of these processes.

The special kind of compound that results from the union

[1] The flame of an alcohol lamp is not hot enough to produce the changes described in this experiment.

of oxygen with a substance is called a compound of oxidation, and the actual formation is called *oxidation*. When oxidation takes place rapidly, light and heat are produced at the same time and the process is called *rapid oxidation* or *combustion*. Give examples from your experience of both kinds of oxidation — the slow and the rapid. Why does the exclusion of air from a fire cause the fire to go out? What is the precise action of water or sand when thrown on a flame, in the light of the above explanation? Write a full statement of what took place in the above experiment.

XI. — Properties of Oxygen

Apparatus. — Chlorate of potash (potassium chlorate), manganese dioxide, piece of phosphorus, stick of charcoal, sulphur, fine iron wire, Florence flask, one-holed rubber stopper, rubber and glass connecting tubing, wash bottle fitted with two-holed stopper, ring stand, sand bath, pneumatic trough, five large-mouthed glass bottles with glass plates to cover, caustic soda, Bunsen burner or alcohol lamp, deflagrating spoon.

Directions. — Set up the apparatus as in Fig. 5. Place in the flask to a depth of half an inch a mixture of one part of manganese dioxide to four parts of chlorate of potash. Fill the wash bottle about half full of water and dissolve a stick of caustic soda in it.[1] When everything is connected as in the diagram heat the flask gently on the sand bath. The first of the gas produced will mix with the air in the apparatus and should be allowed to escape. When the bubbles of gas flow freely through the delivery tube, fill one of the bottles with water and invert over the delivery tube to receive the gas (oxygen) as in the above diagram (see Exercise II on page 14). When the bottle is full cover with the glass plate and set aside, mouth upward. Fill

[1] This will absorb the impurities in the oxygen.

the other four bottles in the same way. Then proceed as follows:

A. Examine the gas in the first bottle. Describe its color and odor. Suck a little into the mouth with a glass tube. Has it any taste?

B. Tie a piece of charcoal to the handle of the deflagrating spoon, heat the end of the charcoal until it glows, and

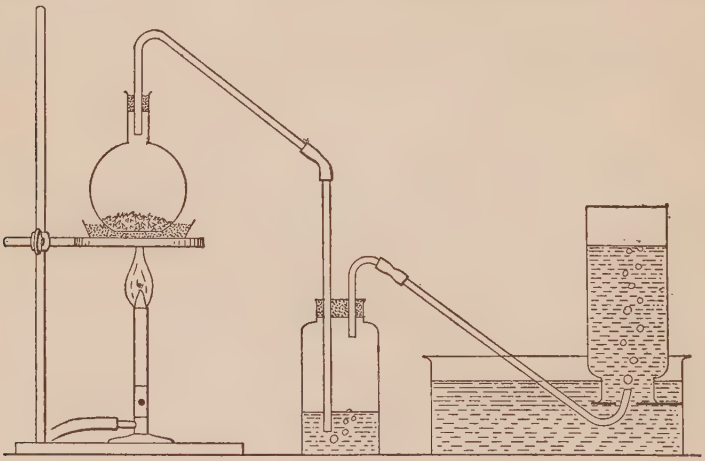

FIG. 5.

introduce it into the second bottle. Describe the result. Keep lowering the charcoal as it tends to stop burning, until it reaches the bottom of the bottle. Compare this result with that of Ex. X. What name do you give to this process? How could you test the contents of the bottle to prove your statement? Do so and record result (see Ex. VIII).

C. Place in the bowl of the deflagrating spoon a piece of phosphorus the size of a pea (Caution! Handle with forceps and cut under water.) Light the phosphorus and introduce quickly into the third bottle. Describe the result.

Does it burn more or less brilliantly than in air? Note the white cloud in the bottle. (This is an oxide of phosphorus and is formed by the uniting of the phosphorus and the oxygen.) Compare this result with that in *B*.

D. After cleaning the deflagrating spoon place some powdered sulphur in it. Light the sulphur. Note how it burns in air and the color of the flame. Now introduce it into the fourth bottle. Describe the result. After the burning is over smell (Caution!) the gas in the bottle. Compare with the odor of burning sulphur in Ex. VII. What is the name of this gas? Is the action noted above combustion? Give your reasons. (See Ex. X.)

Fig. 6.

E. Heat the end of the fine iron wire red hot and introduce it into the fifth bottle. Describe the result. After the action is over examine the red spots on the sides of the bottle and compare them with the rust obtained in Ex. IX. What is the difference between the two actions?

Name the properties of oxygen that you have observed.

XII. — Composition of Air and Properties of Nitrogen

Apparatus. — Pneumatic trough, bell jar closed at the top, evaporating dish, test tube, phosphorus.

Directions. — Fill the pneumatic trough so as just to cover the support. Place the evaporating dish on the support. Place in it a piece of phosphorus the size of a pea; light the phosphorus, and cover quickly with the bell jar.

A. Note the white fumes that appear. What are these? (See Ex. XI, *C*.) What is one of the components of air? When the jar is first put on, note that some bubbles are forced out because the heat causes the air to expand a little. The

phosphorus stops burning when all the oxygen in the bell jar is used up. Let the apparatus stand until the white oxide of phosphorus has been absorbed by the water and the gas in the jar is clear. (Phosphorus was used instead of sulphur or charcoal in this exercise because its oxide is a solid which settles and dissolves in the water.) Has the water risen in the jar? What part, by volume, of the jar does it occupy? Since the phosphorus has used up all the oxygen in burning, about what part of air must be oxygen?

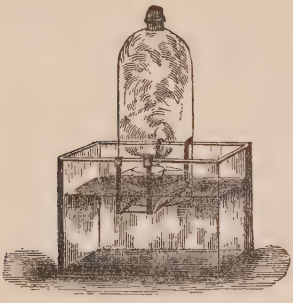

FIG. 7.

B. Fill the test tube with gas from the bell jar in the manner described in Ex. II, *B.* Examine this gas. Describe its color, odor, taste. Place a lighted match in it. What happens? Explain. (This gas is called *nitrogen.*[1]) Of what advantage is the presence of nitrogen in the air? Why is a good draft necessary to make a fire burn freely? If the body needs to take in oxygen constantly why can we not live in a sealed room? Compare the properties of nitrogen, air, and oxygen.

XIII. — COMPOSITION OF WATER (OPTIONAL)

Apparatus. — Electrolysis apparatus,[2] sulphuric acid, four dry cells, splinters of wood, test tubes, pneumatic trough or other dish of water, glass and rubber connecting tubing.

[1] Other gases (carbon dioxide, argon, water vapor) are present in very small proportions.

[2] For the electrolysis apparatus shown on p. 27 may be substituted simpler forms with nearly as good results. Simple forms are shown in Clark and Dennis's "Elementary Chemistry," page 33, and in Remsen's "Chemistry, Briefer Course."

Directions. — Open the two stopcocks and fill the apparatus with water containing 5 per cent of sulphuric acid. When the tubes are full and all air is driven out, close the cocks; arrange the four dry cells in series (positive pole of one connected with negative pole of the next, and so on), and connect the positive and negative poles of the series with the posts as indicated in Fig. 8. Note what happens. Where do the bubbles form? In which tube do they form most rapidly? What is the ratio by volume of the gases in the two tubes?

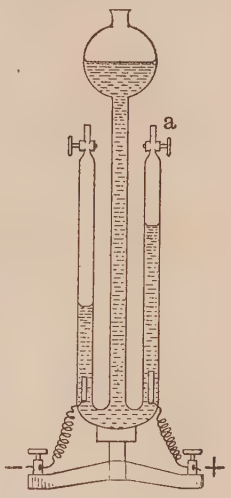

Fig. 8.

When the tube containing the most gas is full, disconnect the cells. Collect in a test tube the gas from the tube containing the lesser amount as follows: With rubber tubing connect an ordinary delivery tube, filled with water, to the top of the gas tube. Insert the end of the delivery tube into the mouth of the test tube, after filling the test tube with water and inverting, as in Ex. II. Open the cock and collect the gas, as in Fig. 9. Cover the mouth of the tube with the thumb and hold it mouth upward. Now remove the thumb and quickly insert a lighted splinter into this collected gas. What happens? What gas have you studied that produces a similar action? This is the same gas.

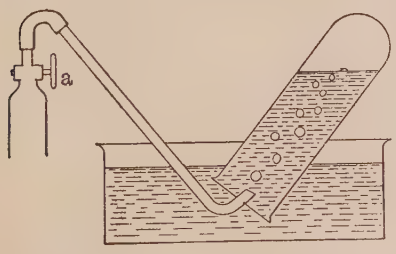

Fig. 9.

In a second test tube collect the gas in the other tube. Hold it mouth downward, and introduce a lighted splinter into it. Describe what happens. How is this gas different from oxygen? from nitrogen? (The name of this new gas is *hydrogen*. The electric current has dissociated the compound — water — into two parts hydrogen and oxygen.) Is this exercise synthesis or analysis?

XIV. — Properties of Hydrogen (Optional)

Apparatus. — Granulated zinc or pieces of sheet zinc, dilute sulphuric acid,[1] bottle with two-holed stopper, thistle tube, glass and rubber connecting tubing, pneumatic trough, large-mouthed bottle, test tubes.

Directions. — Set up the apparatus as in the diagram. Place a handful of zinc in the bottle and pour on enough dilute sulphuric acid through the thistle tube to cover the zinc. (Caution! Keep all flames away from the apparatus until the gas is collected.) Let this gas escape until it is bubbling freely from the delivery tube; then collect the large bottle full, through water, as in Ex. XI.[2]

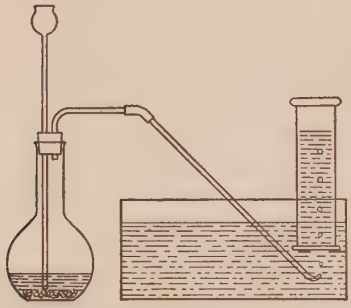

Fig. 10.

A. By the method of Ex. II, *B*, take some of the gas in a test tube and examine it, holding the test tube mouth downward. Describe its color, odor, taste.

[1] To dilute sulphuric acid, pour slowly one part of concentrated acid into five or six parts of water. Stir while pouring.

[2] The gas will be freer of impurities if passed through a wash bottle containing permanganate solution.

B. Collect a second test tube full and hold mouth downward as before. Tie a match to a wire, light the match, and thrust it up into the tube. Does the match continue to burn? Reason? Where does the hydrogen burn? Why? After the hydrogen has burned up, examine the sides of the tube. What do you find on them? Why should you expect this? What is oxide of hydrogen?

C. Hold a fresh tube full of hydrogen mouth upward for a few moments. At the end of that time test with a match. Is the hydrogen still there? Explain. (Hydrogen is the lightest substance known.) Make a list of the properties of hydrogen.

XV. — Acids, Bases, Salts, and Neutralization.

Apparatus. — Dilute hydrochloric and nitric acids (one part acid to ten parts water), caustic soda, red and blue litmus paper, evaporating dish, glass stirring rod, Bunsen burner.

Directions. — *A.* Examine some of the dilute hydrochloric acid. What sort of odor has it? Describe its taste. Rub some between the fingers; describe its "feel." Dip a piece of red litmus into it. What is the effect? Dip in a piece of blue litmus. Describe the result. (The taste, "feel," and effect on litmus noted are three ways in which to detect an acid.) Test some common substances with red and with blue litmus and record results; *e.g.*, cream of tartar, vinegar, soda, fruit juices, ammonia.

B. Dissolve a stick of caustic soda, an inch long, in a tumbler of water. Examine this liquid. What is its taste? odor? "feel"? Test it with the two kinds of litmus paper and record results. (This kind of substance is called a *base*. Bases always react in this way to taste, "feel," and litmus.

Certain strong bases are called *alkalis.*) Test the substances named in *A*. Which of these are bases?

C. Pour some of the caustic soda solution into the evaporating dish. Add, gradually, the dilute hydrochloric acid, stirring with the rod and testing with the litmus until the solution turns neither red litmus blue nor blue litmus red. If too much acid is added correct it with more basic solution. The acid and the base are now said to be *neutralized*, and the process is called *neutralization*. Evaporate this mixture to dryness over the flame. What sort of substance is left in the dish? Taste it. Is it familiar? Does it affect litmus in the solid state or when dissolved in water?

D. Repeat the above neutralization, using nitric acid instead of hydrochloric. Does the product affect litmus?

(The products of *C* and *D* are called *neutral salts*. To this class of substances belong most of the minerals of the earth.) This exercise may be continued with other acids and bases at the desire of the experimenter.

STUDY OF NUTRIENTS

Phosphorus, sulphur, carbon, iron, oxygen, nitrogen, and hydrogen are a few of the chemical elements to be found in plant and animal bodies. These elements occur, however, not as elements, but in combinations, or compounds. There are many of these combinations, but they may be grouped together under a few class names. These classes of compounds show certain definite qualities by means of which their presence may be detected. The classes are called *proximate principles*, or *nutrients*. The most important are:

Proteins, or nitrogenous compounds.[1]
Carbohydrates, or starches and sugars.
Fats and oils.
Mineral salts.
Water.

XVI. — Proteins

Apparatus. — Raw white of egg, olive oil, salt, nitric acid, ammonia, Millon's reagent,[2] Biuret reagent,[3] test tubes.

Directions. — *A*. Put a little raw white of egg (a good example of protein) in a test tube, cover with two inches of water, and shake. Does the white of egg dissolve? Shake the mixture and note the result. Heat the water

[1] The American Biochemical Association has revised its nomenclature and agreed upon the use of the word protein to designate this class of compounds, restricting the word proteid to a definite group under the general class of proteins.

[2] To make Millon's reagent, mix one part of mercury by weight with two parts of nitric acid (concentrated commercial); when the mercury is all dissolved, dilute with twice the volume of water.

[3] To make biuret reagent, make first 1000 c.c. of 20 per cent solution of caustic soda in water. Then to this add (a few drops at a time with constant stirring) 10 c.c. of 3 per cent copper-sulphate solution.

and egg mixture slowly. What form does the white of egg take now? Is this form soluble in water?

Put a second portion of the egg in a test tube. Add dilute nitric acid to it. What happens to the white of egg? Compare the action with that in boiling water.

(This action of acid and heat on a protein like egg albumin is called *coagulation*.) Why does a piece of meat (which is composed mainly of a protein like white of egg) become more solid under heat?

B. Xanthoproteic Test. Place a little coagulated white of egg in a test tube and cover with dilute nitric acid. Heat to boiling, and then add enough ammonia to neutralize the acid and give an alkaline test. The white of egg (protein) takes what color? Treat in the same way some olive oil, some common salt, and any other substance that does not contain protein. Do any of these take the same color as the white of egg?

C. Millon's Test. Add enough Millon's reagent to a little coagulated white of egg to cover, and raise the temperature *gradually* by holding the test tube several inches above the flame. What color does the egg and the solution become? Treat the other substances mentioned in *B* in the same way. Do they act like the egg?

D. Biuret Test, or Piotrowski's Reaction. To a little white of egg in water add 10 c.c. of biuret reagent. Note the color change. Boil the mixture. Does the color change? Note the result. Test the other substances mentioned in *B* in the same way.

(Of the three chemical tests for protein given above, the xanthoproteic is best for general use. There are many forms of protein, but these tests will indicate its presence whatever its form may be.)

XVII. — Carbohydrates — Starch

Apparatus. — Solution of iodine,[1] laundry starch, white of egg, olive oil, test tubes.

Directions. — Place a little starch in a test tube and fill the tube a quarter full of water. Shake it. Does the starch dissolve? Prove your statement by applying one of the tests described in Exercise V. Boil. What happens to the starch?

Put a little of the starch paste in a test tube with an inch of water. (Shake, to get thorough mixture.) Now add a drop of the solution of iodine. What color does the paste become? Heat. What becomes of the color? Should the iodine test be applied to hot or cold starch-containing substances?

Test a little white of egg and olive oil (which contain no starch) in the same way. Do you get the same result?

(This test will indicate the presence of starch, whatever may be its form.)

XVIII.— Carbohydrates — Grape Sugar (Glucose) and Cane Sugar (Sucrose)

Apparatus. — Fehling's solution[2] or Benedict's solution,[3] glucose, starch, oil, test tubes, concentrated hydrochloric acid, cane sugar.

[1] To make the iodine solution, dissolve a teaspoonful of potassium iodide crystals in a tumbler of water. Add crystals of iodine and stir until a rich wine color is obtained. This may be bottled and used as needed.

[2] To make Fehling's solution:

Fehling's solution is composed of two definite solutions — a cupric sulphate solution and an alkaline tartrate solution.

Cupric sulphate solution = 34.65 grams cupric sulphate dissolved in 500 c.c. of water.

Alkaline tartrate solution = 125 grams potassium hydroxide or sodium hydroxide and 173 grams of Rochelle salts dissolved in 500 c.c. of water. Keep these solutions separate until ready for use. Prepare for test by mixing equal portions.

[3] Dr. S. R. Benedict has devised a substitute for Fehling's solution

Directions. — *A.* Dissolve a little of the glucose in water in a test tube. Add 5 c.c. of Benedict's solution (or Fehling's solution) and heat to boiling. Note any changes in color. When no further change in color takes place, note the final color. Let the solution stand and note that the colored part separates out as a precipitate. Test in the same way oil, starch and any other substance that contains no grape sugar. Compare results.

(This is a universal test for grape sugar.)

B. Test for Cane Sugar (Sucrose). To 5 c.c. of a weak solution of cane sugar add an equal volume of concentrated hydrochloric acid. Boil. A deep red color indicates cane sugar.

XIX. — Fats and Oils

Apparatus. — Flaxseed (ground), beef fat, unglazed paper, ether, filter paper, glass funnel, evaporating dish, chemical thermometer.

Directions. — *A.* Put a little beef fat in the evaporating dish and heat. When it begins to melt stir with the chemical thermometer and note the temperature of the melting point. If the body temperature is 98° F. what does this experiment indicate as to the condition of fats in the body? Name some fats that are liquid at ordinary temperatures.

which has the advantage of not deteriorating on long standing. It is prepared as follows:

"With the aid of heat dissolve 173 grams of sodium citrate and 100 grams of sodium carbonate in about 600 c.c. of water. Pour through filter paper into a glass graduate and make up to 850 c.c. with water. Dissolve 17.3 grams of cupric sulphate in 100 c.c. of water and make up to 150 c.c. with more water. Pour the carbonate-citrate solution into a large beaker and add the cupric-sulphate solution slowly, with constant stirring. The mixed solution is ready for use and does not deteriorate on long standing."—Hawk's "Practical Physiological Chemistry," 1910.

B. Place a little beef fat on the unglazed paper and warm. Remove and examine the paper. How does it show the presence of fat? Substitute for the beef fat a little ground flaxseed and repeat the above process. Does flaxseed act like beef fat? Do starch and other substances which contain no fat or oil act in the same way? (The above is a general test for fats and oils in whatever form they may be.)

C. Burn a little fat and note the odor. This odor is characteristic of fats.

D. Place a little beef fat in a test tube. Add enough ether to cover, and shake. Describe the effect on the fat. Filter off the ether, by means of the funnel and filter paper, into the evaporating dish. Let the latter stand until the ether evaporates. What is left in the dish? What did the ether do to the fat? Treat ground flaxseed in the same way. Is the result the same? Treat sugar, or anything else that contains no fat or oil, in the same way. Is the result the same? (The above method enables us to extract fat from a substance which contains it.)

XX. — Mineral Salts (Optional)

Apparatus. — Platinum foil or piece of sheet iron, forceps, piece of meat or vegetable matter.

Directions. — Place the meat on the foil and hold the foil in the flame with the forceps until all the black has disappeared from the burning meat. The residue is mineral matter. Would this test be possible if this mineral matter were combustible? What color is the residue? (This is the method for determining the presence and amount of mineral salts.)

XXI. — Water (Optional)

Apparatus. — Pieces of parsnip, potato, apple, lettuce leaves, flour, meal, meat, test tube, balance sensitive to one gram.

Directions. — *A*. Heat one of the above substances in a dry test tube. As the tube cools after having been taken from the flame, examine the sides and note what you see on them.

B. Weigh a portion of each of the above substances, record the weights, and place the substances in a warm, dry place for a few days. Then weigh again and record as before. Continue this until there is no further decrease in weight. The loss of weight represents approximately the water contained in the substances before it evaporated. From your results answer the following questions: About what per cent of water did each substance contain? Why are flour and grains in general a good food for travelers to carry? Why are fruits and salads good hot-weather foods?

STUDY OF FOODS

XXII. — Necessity of Food

Apparatus. — Wide-mouthed bottles, corks to fit, pea or corn seedlings, nutrient solution,[1] test tubes, paraffin wax, distilled water.

Directions — *A*. Take one of the pea or corn seedlings and cut off the cotyledons close to the stem. Pass this through a hole in one of the corks, and insert in a bottle, as shown in Fig. 11. Fill the bottle about three-quarters full of the nutrient solution. Prepare a second seedling in the same way (select one of as nearly the same size as possible), but substitute distilled water for the nutrient solution. Note the growth of each seedling for several days. Do they grow equally fast? What sort of food is in the nutrient solution? From the composition of the water and the mineral salts, is it possible for the plant to get its carbon from the nutrient solu-

Fig. 11.

[1] Nutrient Solution after Sachs ('82):

Distilled water (H_2O)	1000.00	c.c.
Potassium nitrate (KNO_3)	1.00	gram
Sodium chloride ($NaCl$)	0.50	"
Calcium sulphate ($CaSO_4$)	0.50	"
Magnesium sulphate ($MgSO_4$)	0.50	"
Calcium phosphate ($Ca_3[PO_4]_2$)	0.50	"
Ferric chloride ($FeCl_3$)	0.005	"

(Do not put the ferric chloride into the solution in the first place, but add a drop of it to each bottle when the seedlings are put in.)

tion? (Air contains a small proportion of carbon dioxide [see Ex. XII] and plants secure their carbon through their leaves, which absorb the gas from the air.) From your observations can a plant live indefinitely on water alone?

B. Seal the growing seedling of *A* to the cork with melted paraffin wax, cover the upper part of the seedling with a test tube, and seal the edges of the tube to the cork. Does the plant continue to live? (Plants cannot live without air.) What collects on the inside of the tube? What evidence have you that a plant gives off water?

C. Prepare a third and a fourth seedling as in *A*. In one bottle put some nutrient solution made without the potassium nitrate, and in the other the normal solution. Which seedling lives longest? (To support life, one food required by plants is some nitrogen salt like potassium nitrate.)

D. Prepare a fifth seedling as in *A*, using a nutrient solution with only the ferric chloride omitted. After several weeks, notice the effect on the color of the plant.

XXIII. — Nutrients Present in Common Foods

Apparatus. — Meat, flour, milk, parsnip, lettuce, peanuts, and the necessary materials for the tests described in Exs. XIII to XVIII.

Directions. — Apply the tests to each substance separately and tabulate your results as follows:

Substance Tested. — .....

Name of Test	Reagent Used	Color or Other Result	Nutrient Indicated

Under " Reagent " tell the chemicals used.

Under " Color or Other Result " state exactly what happens.

Under " Nutrient Indicated " write the name of nutrient and the word present or absent.

XXIV. — Study of Food Charts [1]

Food	Composition Percentage of Nutrients						Energy in Calories per Pound	Average Cost per Pound
	Protein	Starch	Other Carbohydrate	Fat	Water	Mineral		
Bread (White)	8.	47.	3.	1.	37.	2.	1280.	$ .04
Flour	11.	66.	4.2	2.	15.	1.7	1645.	.025
Oatmeal	12.6	58.	5.4	5.6	15.	3.	1850.	.05
Rice	6.	79.	0.4	0.7	13.	0.5	1630.	.07.
Beans	23.1	55.	2.	2.	12.6	3.1	1615.	.05
Potatoes	2.	18.	3.	0.2	76.	0.7	375.	.0125
Milk	4.	—	5.	4.	86.	0.8	325.	.035
Cheese	28.3	—	1.8	35.5	30.2	4.2	2070.	.16
Beef (Round)	20.5	—	—	10.1	68.2	1.2	805.	.14
Beef (Corned Flank)	14.2	—	—	33.	49.8	3.	1655.	.10
Mutton (Leg)	18.3	—	—	19.	61.8	0.9	1140.	.18
Veal (Shoulder)	20.2	—	—	9.8	68.8	1.2	790.	.20
Pork (Shoulder—Fresh)	16.	—	—	32.8	50.3	0.9	1680.	.16
Pork (Ham)	16.7	—	—	39.1	41.5	2.7	1960.	.16
Pork (Salt Fat)	0.9	—	—	82.8	12.1	4.2	3510.	.12
Chicken	24.4	—	—	2.	72.2	1.4	540.	.20
Eggs	14.9	—	—	10.5	73.8	0.8	721.	.18
Butter	1.	—	0.5	85.	10.5	0.3	3615.	.30
Codfish	15.8	—	—	0.4	82.6	1.2	310.	.08
Mackerel	18.2	—	—	7.1	73.4	1.3	640.	.12
Oysters	6.	—	3.7	1.2	87.1	2.	230.	.25

Dietary Standards

Conditions	Protein	Carbohydrates	Fat	Calories
Man with light muscular exercise	0.22 lbs.	0.88 lbs.	0.22 lbs.	2980.
Man with moderate muscular exercise	0.28 lbs.	0.99 lbs.	0.28 lbs.	4520.
Man with active muscular work	0.33 lbs.	01.10 lbs.	0.33 lbs.	4060.

[1] More extensive tables may be found in a pamphlet printed by the Department of Agriculture, Farmer's Bulletin No. 23, " Foods, Nutritive Value and Cost," by W. O. Atwater. See also Bulletin No. 13, Series I, March, 1909, of the American School of Home Economics.

Questions to be answered from study of Food Chart.

Fat and carbohydrates are the energy producers: how does the table show this? What sorts of foods are richest as protein furnishers (tissue builders)? Of the animal and vegetable foods, which are richest in protein? fat? carbohydrates?

Calculate the cost, amount of energy in calories, and per cent of nutrients, in the following daily dietaries:

(*a*) 13 ounces of beef (round), 3 ounces of butter, 6 ounces of potatoes, 22 ounces of bread.

(*b*) 4 ounces of salt pork, 2 ounces of butter, 16 ounces of beans, 8 ounces of bread.

(*c*) 10 ounces of beef (corned), 1 ounce of butter, 16 ounces of milk (pint).

Make up a suitable daily dietary for each of the three different classes of men given in the table.

HISTOLOGICAL STUDIES

XXV. — Parts of a Cell

Apparatus. — Scalpel, compound microscope [1] with two-thirds and one-sixth inch objectives and one inch ocular, glass slides and cover glasses, pieces of filter paper, methyl green or Delafield's hæmatoxylin.[2]

Directions. — Sterilize the scalpel by holding it in boiling water, then scrape the inside of the cheek lightly with the

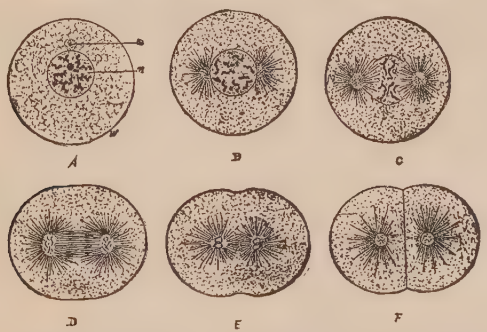

Fig. 12. — *A*, diagram of a cell; *w*, cell wall with enclosed cytoplasm; *n*, nucleus, consisting of nuclear membrane inclosing granular substance, in which are seen a spherical nucleolus and irregular masses of chromatin; *a*, centrosome; *B–F*, changes that take place during cell division.

blade. When the scalpel is removed from the mouth there will appear on it the scrapings in the form of a white sediment. Remove a little of this sediment and mount in a

[1] Bausch & Lomb and the Spencer Lens Company furnish at request a pamphlet describing all the parts of the microscope and the method of handling the instrument.

[2] For the preparation of these stains consult any manual of microscopy. Lee's "Vade Mecum" or Guyer's "Animal Micrology" is recommended.

drop of water on the slide. Cover with the cover slip and examine with the two-thirds objective (low power). In focusing, the best results are obtained if nearly all the light is excluded by the diaphragm.

Draw what you see. Note that the masses are made up of separate elements (*cells*). Compare with Fig. 12, *A*. Are the walls circular, as in the figure?

Place a drop of the methyl green at one side of the cover slip and by placing the filter paper at the opposite side draw this solution under the slip. Let the slide stand for a moment and examine again with the low power. What part of the cell has changed color? (This part is called the *nucleus* of the cell.)

Now focus on one of these cells with the one-sixth objective (high power). Has the cell a definite outline? Note the clear liquid between the nucleus and the outline. Do you notice any particles floating in this liquid? Draw this cell, magnified to an inch diameter, and label as follows: the outside boundary or *cell wall;* the clear liquid or *protoplasm;* the particles floating in this protoplasm, or *granules;* the *nucleus.*

XXVI. — Study of a Plant Cell

Apparatus. — Pond scum (Spirogyra), physiological salt solution,[1] materials described in Ex. XXV.

Directions. — Mount a little of the pond scum in a drop of water and cover with a glass. Examine with the low power. Do you see any separate units in this case? How are they arranged? What is their color? Is this color evenly distributed throughout the cell or located in definite

[1] Physiological salt solution is made by adding 6 grams of common salt (NaCl) to 1 liter (1000 c.c.) of distilled water.

parts of the cell? Can you see any cell wall? protoplasm? nucleus? Make a drawing of what you see and label in such a way as to answer the above questions.

Now add a little of the physiological salt solution, to be run under the cover glass, and examine with the high power. Do you see any nucleus now? any protoplasm? What has happened to the protoplasm? Draw and label such parts of the cell as show. A little methyl green or Delafield's hæmatoxylin added will make the nucleus more distinct.

Make a list of the differences and similarities between the cells examined in Ex. XXV and Ex. XXVI.

NOTE. — The comparison of cells should be further demonstrated with other materials by the instructor, until the essential and variable components are clearly grasped by the pupil. Some suggested material: Pleurococcus, potato, diatoms, root tips, etc.

XXVII. — STUDY OF LIVING PROTOPLASM — AMŒBA

Apparatus. — About a month beforehand collect the leaves and sediment from pools of still but clear water. Distribute this material — together with a few water plants (Nitella or Chara) — in several open, shallow dishes. Keep covered with water. When, in course of time, the water in these has become clear and free from scum, take up with a pipette (medicine dropper) some of the sediment from the very surface of the leaves. Examine this for amœbæ with the low power (two-thirds objective). When the dish containing them in quantity is located, mark this for supply.[1] The other apparatus is the same as in Ex. XXV.

[1] A. W. Weysse of Boston University gives in "Science," Vol. XX, No. 515, the following method of securing amœba. Collect a considerable number of lily pads. Remove with a spatula the slime which adheres to the lower surface and put it in a shallow glass aquarium containing water six or eight centimeters deep. Place the vessel near a window, and in a week or two amœbæ will be abundant on the surface of the sediment at the bottom.

Directions. — Mount some of the amœbæ on a glass slide and cover them with a cover slip. Locate one of the animals with the low power and then focus on it with the high power for careful observation.

Watch the amœba until it begins to show movement, then draw and note the following parts: round, opaque *nucleus*, the clear outer part (*ectoplasm*) and the granular inner part (*endoplasm*) of the *cytoplasm*. (Cytoplasm is the name given to that part of the protoplasm which is not nuclear, since the nucleus is also composed of protoplasm.) Note, further, the round spots in the cytoplasm (*vacuoles:* food vacuoles, water vacuoles, or contractile vacuoles, according to contents); the constantly forming projections of the cytoplasm (*pseudopodia*); and the absence of any cell wall.

(Amœba is a one-celled animal made up of free protoplasm, and hence well suited to show the properties of this substance, which is the physical basis of all life.)

Properties of Protoplasm

A. What color is the cytoplasm? Does it appear thicker or thinner than the water? Is the part containing granules of the same color as the clear part? Does this cytoplasm mix with the water? Describe the appearance of the nucleus.

B. Movement. Watch the moving amœba. Note the various steps in the forming of a pseudopodium. Is the movement of the animal rapid? Does it appear to move in a definite direction or at random? Do the particles in the water appear to affect its movement? Press on the cover glass with a needle point just above the amœba. How does the amœba react? Note that the movement of the amœba is produced as a result of two properties of protoplasm,

contraction and *expansion*. A substance showing these properties when it is stimulated is said to have *contractility*.

C. In *B* we noted that the animal contracted and ex-

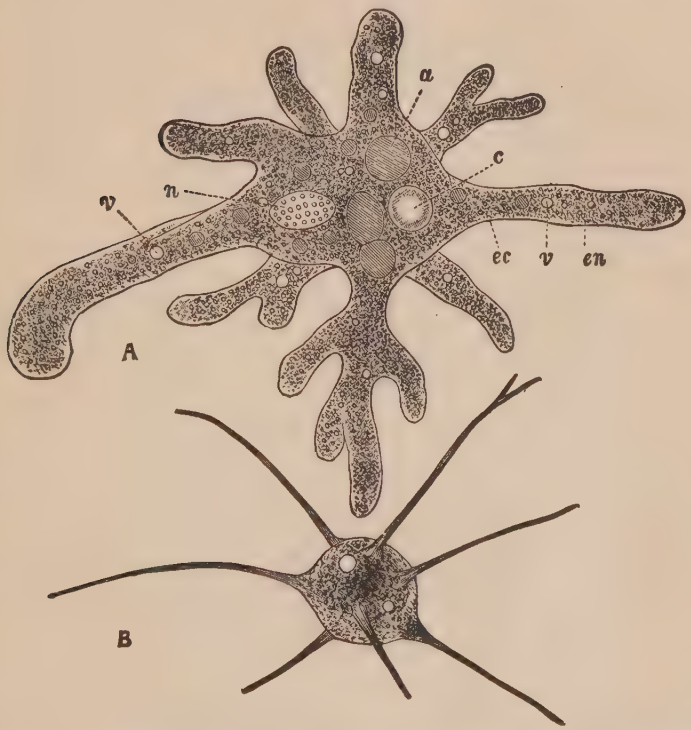

FIG. 13. — *A*, *Amœba proteus: a*, food vacuole; *c*, contractile vacuole; *ec*, ectoplasm; *en*, endoplasm; *n*, nucleus; *v*, water vacuoles. *B*, *Amœba radiosa*.

panded without apparent cause in some cases. We noted also that under pressure it contracted more strongly. This power to respond to special stimuli is called *irritability*. Test the irritability of the protoplasm toward heat by applying the flame of an alcohol lamp gently to the end of

the glass side. Record your observations as the heat gradually increases. Other tests may be made by running solutions of various salts, etc., under the slide.

D. Feeding Habits. Examine the contents of some of the vacuoles and state your conclusions as to the form of food taken in by the protoplasm. Note and describe the method of engulfing these food particles and the forming of the vacuole. Compare several of these vacuoles as to the condition of their contents. From these observations, what do you conclude happens to food in the amœba?

(The process of taking in food is called *ingestion.* The process of dissolving ingested food is called *digestion.* The process of transforming digested food into protoplasm is called *assimilation.* This last process is evidenced by the decreasing size of the vacuole after the food is dissolved.)

E. The Removal of Wastes. Study the action of the large contractile vacuole. What does it appear to contain when expanded? Where does this substance come from? Where does it go when the vacuole is contracted? Does the vacuole pulsate regularly?

(The process of collecting the broken-down waste of the body and its removal to the outside is called *excretion.* The processes described in *D*, by means of which protoplasm is made, are spoken of collectively as *anabolism.* The processes by means of which old protoplasm is broken down and removed are spoken of collectively as *katabolism. Metabolism* is the simultaneous occurrence of these two actions in a living body of protoplasm.)

F. Place several amœbæ in a drop of water in a vial and cork the vial tightly. The water used should be rich in food — bacteria. Also, for comparison, make a balance preparation consisting of the same number of amœbæ mounted

in the same amount of water in a watch glass, this preparation to be exposed to the air in a large vessel containing a little water to prevent evaporation. Examine at the end of a few days. What evidence have you that protoplasm requires air?

(It is the oxygen in the air that the animal uses. This property of taking in air and oxygen is part of a process called *respiration.*)

Make a list of all the properties of protoplasm as exhibited by the cytoplasm of the amœba.

XXVIII. — Epithelial Tissue (Optional)

Apparatus. — Prepared slide[1] of cross section of the small intestine (human preferred, but rat's or other mammal's will serve), compound microscope.

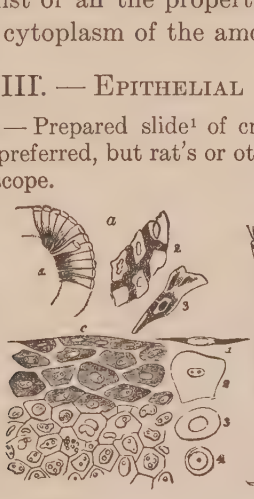

Fig. 14. Fig. 15.

Epithelial Tissues. *a*, two forms of epithelial tissue: 1, columnar; 2 and 3, squamous; *c*, stratified tissue; *b*, simple ciliated tissue; *d*, ciliated columnar tissue.

Directions. — Focus with the high power on the cells forming the inner layer of the intestine. Draw six or eight

[1] Prepared slides for study of tissues may be bought best of dealers, as their preparation is a matter of delicacy and skill. For those who wish to prepare their own, suitable directions will be found in standard histologies, such as Stöhr's or Schäfer's, and in Lee's "Vade Mecum" or Guyer's "Animal Micrology."

of these cells, showing the large nucleus in each, the general outline of the cells, and the distribution of the protoplasm. Note the thinness of the cell wall and the absence of intercellular material. Compare these cells (*columnar epithelium;* see Fig. 15, *d*) with those of Ex. XXV (*squamous epithelium;* see Fig. 14, *a*, 2 and 3, and *c*). How do they differ? Note the protective character of these layers of cells with reference to the underlying layers. (One feature of this protection is prevention of the action of digestive fluids upon the underlying muscles and other forms of tissue.)

XXIX.— Connective Tissue (Optional)

Apparatus. — Prepared slides of intermuscular tissue, cartilage, and bone, compound microscope.

Directions. — *A. Intermuscular Tissue.* Draw, under the low power. Note two classes of bundles of fibers (*white fibers* and *elastic*). The elastic fibers are single and are more sharp in outline than the white. Find one of the cells (or corpuscles) and focus with the high power. Draw it, and show in your drawing its relation to the two classes of fibers. From your study, which part of this tissue should you say was most important, the cellular part or the intercellular fibers?

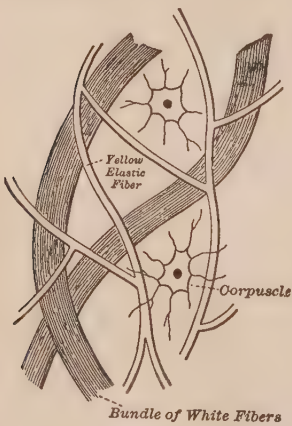

Fig. 16.—Intermuscular Tissue.

B. Cartilage (*hyaline*). Note the solid character of the intercellular matrix, the outlines of the cells with their protoplasm and nucleus, the *lacunæ*, or pits in which the cells

lie, and the capsules inclosing these lacunæ. Which part of this tissue is supporting, the cells or the matrix? Draw a section, under the high power, and label all parts.

C. Bone. Note the matrix of spongy bone arranged in concentric rings (*lamellæ*) around the central canals (*Haversian canals*). Between the lamellæ note the irregular cavities *lacunæ*) with their wavy branches or *canaliculi*. Note how these canaliculi connect the lacunæ with one another and with the Haversian canals. Look in the lacunæ for the bone cells.

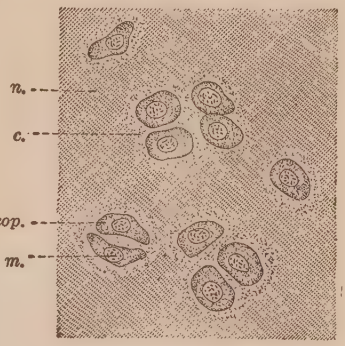

FIG. 17.—Hyaline Cartilage: *cap*, capsule; *m*, matrix formed by cells; *c*, cartilage cell; *n*, nucleus.

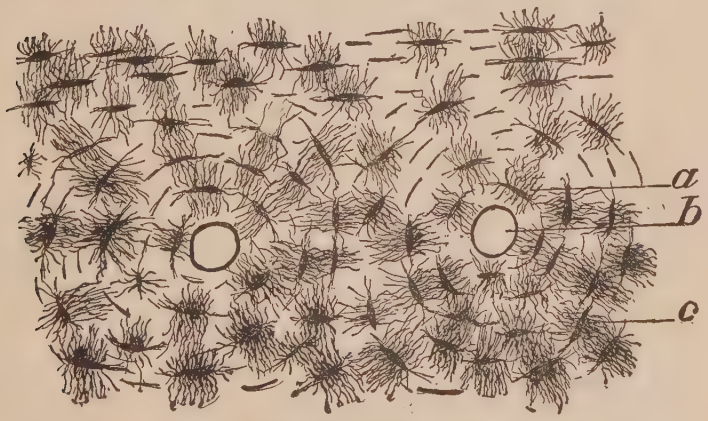

FIG. 18. — Bone: *a*, canaliculi; *b*, Haversian canal; *c*, lacuna.

(In ground sections of bone these will probably be wanting. They appear better in sections of decalcified bone.) Draw,

under high power, a section locating all the above-named parts.

(Note in the three classes of connective tissue that the intercellular portion is the important part in support. The importance of the cells becomes clear when it is understood that this intercellular matrix is produced by them.)

XXX. — Muscular Tissue (Optional)

Apparatus. — Prepared slides of striated and non-striated muscle, compound microscope.

Directions. — *A. Non-striated.* Note the long, spindle-shaped cells, the elongated nucleus, and the homogeneous protoplasm filling the whole cell. Note, further, how these cells interlace. (They are held together by a homogeneous cement substance.) Note the absence of any striation, or striping. Draw several of these cells under the high power, locating all the parts mentioned above.

Fig. 19. — A Non-striated Muscle Cell; *n*, nucleus.

B. Striated. Examine a single fiber with the high power. Note the broad, dim, transverse striæ and the narrow, light, transverse striæ. The broad stria is called *anisotropic* or *doubly refracting, contractile sarcoplasm.* The narrow stria is called *isotropic* or *singly refracting sarcoplasm.* Note also the more or less dim longitudinal striation. Over the whole of the fiber is stretched the transparent *sarcolemma,* or cell wall. Somewhere on the fiber may be found also several nuclei. Draw and locate all these parts of the muscle cell. (Sarcoplasm is merely another name for the protoplasm of a muscle cell.)

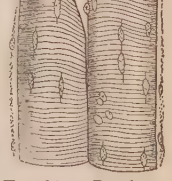

Fig. 20. — Portions of Striated Muscle Fibers. (The figure shows the striæ and the nuclei.)

XXXI. — Nervous Tissue (Optional)

Apparatus. — Prepared slides of ganglion cells and nerve fibers,[1] compound microscope.

Directions. — *A. The Nerve Cell.* Note the irregular outline of the cell; the wavy projections, or *dendrites;* the rodlike projections, or *nerve processes.* Note the position of the nucleus. Has the cell one or more nerve processes? Draw and locate all parts, under the high power.

B. The Nerve Fiber. Make out from your study of the nerve fiber the *axis cylinder* in the center. (This corresponds to the nerve process of *A.*) Next outside this is the *medullary sheath,* and on the very outside the *neurilemma.* Make a drawing showing all these parts. For their relation compare with Fig. 21.

All tissues of the body can be placed in one of the above classes, — epithelial, connective, muscular, or nervous.

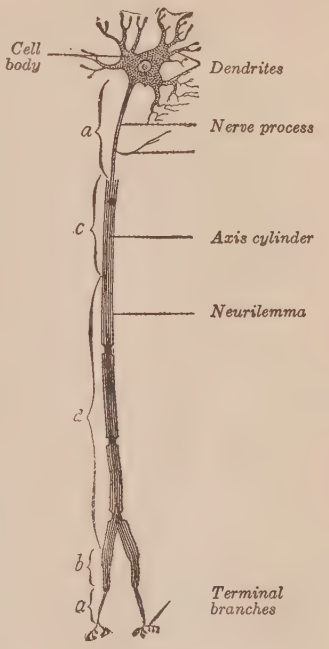

Fig. 21. — Scheme of a Neuron: *a,* free axis cylinder; *b,* axis cylinder surrounded by neurilemma alone; *c,* axis cylinder surrounded by medullary sheath alone; *d,* axis cylinder surrounded by the sheath and neurilemma and divided into segments (by constrictions called the *nodes of Ranvier*).

[1] A smear preparation of spinal cord may be prepared as follows: Rub a piece of fresh spinal cord in water between two cover glasses. Mount and run under the cover glass a drop of methyl green. Both nerve fibers and nerve cells appear in such a preparation.

PRINCIPLES OF DIGESTION

XXXII. — Principles of Osmosis.

Apparatus. — Potassium bichromate, glucose, white of egg, starch, beet root, Fehling's solution, iodine solution, Millon's reagent, dialyzer. There are several forms of dialyzer described by different authors, any one of which will serve. (1) The following form has been found very satisfactory: Take ordinary collodion and a glass beaker. Pour the collodion into the beaker and then pour out again, revolving the beaker so as to bring the collodion into contact with the entire inner surface of the glass. Let the beaker drain for a few moments. The ether will evaporate and leave a thin skin on the inside of the beaker. As soon as the skin is tough enough, loosen it at the top and pour water between it and the glass. With care the entire skin will separate from the glass, giving a membranous bag which is exactly the shape of the beaker, is water tight and ideal for these experiments. Any shape bag may be obtained by selection of the receptacle. (2) Obtain from the butcher some skins such as are used to hold sausage meat. Tie one of these around the base of a student lamp chimney, as in Fig. 22, after cutting off the chimney so that it is only about six inches in height. Select a cork to fit tightly in the top of the chimney and, with a cork borer, puncture this to fit an eighth-inch glass tube about a foot in length. Arrange the whole apparatus as in the diagram, supporting the chimney in an outer jar so that it will not rest on the bottom. To fill the

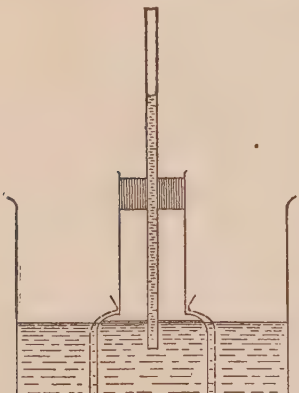

Fig. 22.

chimney, remove the cork and tube. The tube will serve as a delicate indicator of the amount of rise in the water.

Directions. — *A*. Put into the dialyzer some crystals of potassium bichromate. Fill with water both the dialyzer and the outer jar until the level is the same in each. Allow them to stand for a short time. Then examine and note the level of water in the two parts. What has been the prevailing direction of flow of water? Is the color of the water in the outer jar changed? Has some of the salt solution in the dialyzer passed through the membrane? (This interchange of water and salt solution through a membrane — the sausage skin or the collodion — is called *osmosis*.)

B. Place some glucose in a beaker with some water. When the grape sugar is well dissolved, transfer this liquid to the dialyzer. Fill both dialyzer and outer jar to the same level with water as before. Note the direction of the water-flow. Test the water in the outer jar with Fehling's solution. What results? Does grape sugar in solution pass readily through the membrane? (Substances which pass readily in solution through a membrane under the above conditions may be said to osmose.)

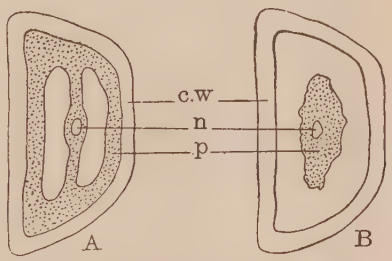

FIG. 23. — *A*, living cell; *B*, cell whose protoplasm has been killed by boiling; *cw*, cell wall; *n*, nucleus; *p*, protoplasm.

C. Substitute for the glucose solution a diluted starch paste. After a time note the level of the water. Record its direction of flow. Test the liquid in the outer jar with iodine solution. Does starch osmose? Does starch crystallize like grape sugar and potassium bichromate?

D. Substitute for the starch paste a solution made of white of egg whipped up in water. Note direction of flow of water. Test the water in the outer jar with Millon's test for proteid. Does egg albumin osmose?

E. Cut a few slices of beet root. Wash, and place a few pieces in two separate beakers. Fill each beaker half full of distilled water. Boil the slices in one of the beakers. (This kills the protoplasm in the cells of the beets without injury to the cell walls.) Add a few drops of hydrochloric acid to each beaker, and then test with Fehling's solution for grape sugar. In which has the sugar dialyzed from the cells? In which is the water colored? Study the arrangement of protoplasm in a dead and in a living cell, as illustrated in Fig. 23, and state your conclusions as to the influence of protoplasm on osmosis.

(Substances that osmose are called *crystalloids*. Substances that do not osmose are called *colloids*.)

F. Make a mixture of grape sugar, white of egg, and water. Put in the dialyzer with water on the outside. After a time test the water with: (*a*) Benedict's or Fehling's solution. Result? (*b*) Biuret reagent. Result? Separation of crystalloids from colloids by osmosis is called dialysis.

XXXIII. — An Enzyme

Apparatus. — Ground malt, starch, test tubes, iodine solution, Fehling's solution.

Directions. — Make an extract of malt diastase (an *enzyme*) by shaking up five grams of ground malt with 50 c.c. of cold water. Let it stand for a few hours and then filter. Make a thin starch paste by mixing a teaspoonful of starch

with a cup of boiling water.[1] Fill two test tubes half full of this starch preparation. Test a little of the starch preparation with the iodine solution, to determine strength of reaction. Test a little of the starch preparation, and also some of the diastase solution, with Fehling's solution. Is grape sugar present in either of them? Now add 10 c.c. of diastase solution to one of the test tubes; warm both tubes, and keep them as near as possible at a constant temperature of 45 C.

At intervals of five minutes remove a little of the contents of each tube with a pipette and test with the iodine solution. Do the same, using Fehling's solution instead of iodine solution. Is the amount of starch on the increase or the decrease in either tube? After how long a time do you get a test for grape sugar, and in which tube? Continue these tests until you get a strong test for grape sugar.

(The reason for these results is that the malt diastase — the enzyme — is slowly changing the starch into sugar. An enzyme is a substance which can bring about the transformation of one chemical compound, such as starch, into another, such as sugar, without itself being used up. The value of enzyme action in our bodies lies in the fact that by it a colloid, like starch, may be changed into a crystalloid, like sugar, which can then be absorbed through a membrane by osmosis, *e.g.*, from the stomach through the walls of the blood vessels into the blood.)

[1] To make clear starch paste, free of lumps, first have the water boiling vigorously. Then mix the starch with a little cold water, shaking to get a milky fluid. Now add the milky fluid, a drop at a time, to the boiling water. Stir constantly while adding the starch. This paste may be kept for a considerable time by adding a little powdered thymol.

XXXIV. — A Ferment Organism — Yeast

Apparatus. — Yeast cake, molasses, eight-ounce bottle, absorbent cotton, limewater, chemical thermometer.

Directions. — Dissolve a piece of yeast cake, the size of a pea, in two tablespoonfuls of water. Pour this into the eight-ounce bottle. Add to this a tablespoonful of molasses and fill the bottle half full of water. Stopper with a plug of absorbent cotton and leave in a warm place for twenty-four hours. Record the temperature of the room in which the bottle is put and the temperature of the mixture.

At the end of the twenty-four hours remove the stopper and examine the contents. What is the temperature? Does it smell sweet? Test the gas in the top of the bottle with a drop of limewater. What gas gives this reaction? Does the odor give you any evidence of the presence of alcohol? Examine under the low power of the compound microscope a little of the sediment from the bottom of the bottle, mounted in water. Draw several groups of the separate elements of this sediment. (These bodies are yeast plants.)

Fig. 24.—Yeast Plants: 1, a plant forming a bud; 2, the bud nearly ready to separate as a new plant.

(Yeast is a one-celled plant that, without changing its yeast character, is capable of transforming sugar into carbon dioxide and alcohol. In its power to change a substance, without itself undergoing transformation, it acts like an enzyme, and hence is called a *ferment organism.* The yeast cell in growing actually secretes an enzyme which produces this change. Hence a "ferment organism" is simply a cell or collection of cells which secrete

enzymes. Many digestive actions are performed by enzymes. Most enzymes are produced in the body by the cells of organs called *glands*.)

XXXV. — Structure of a Typical Gland.

Apparatus. — Microscope and accessories used in the study of tissues, prepared slide of crypt of Lieberkühn from the small intestine of man. (Any other gland preparation will serve.)

Directions. — Examine first with the low power. Draw the entire gland and note the following points: the kind of tissue, the arrangement of the cells, the gland *lumen*, or

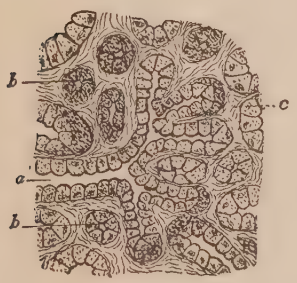

Fig. 25. — A Salivary Gland; *a*, lumen of a gland in longitudinal section; *b*, a gland in cross section; *c*, connective tissue.

Fig. 26.— Forms of Glands.

central cavity. With the high power examine a few of the cells and their contents. Draw, and note the position of the nucleus, the protoplasm, and the secretion in various cells. Fig. 26 illustrates the relation of the simple, tubular gland, such as you have just studied, to the compound forms.

ORGANS AND PROCESSES OF DIGESTION

XXXVI. — Dissection of a Rat's Digestive Organs

Apparatus.— Rat,[1] dissecting tray with wax lining, scissors, forceps, bristle probes, 10 % alcohol or 1 % formalin.

Directions. — Lay the rat on its back in the tray, stretch, and tie or pin the legs as in the diagram. Cover with 10 % alcohol or 1 % formalin.

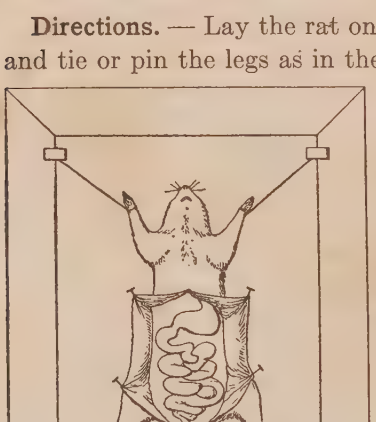

Fig. 27.

Locate the lower end of the breast bone and slit the skin from this point to the anus. On each side, at the middle point of the slit, make a slit at right angles. Turn back the four flaps and pin them.

Note the thin membrane (*peritoneum*) lining the abdomen. Is it flexible? Remove this and, without disturbing the underlying parts, locate the stomach, the liver, and the coiled intestine.

Press the intestine downward and determine the size, position, shape, and color of the stomach. Find the ends

[1] This exercise may be made a demonstration. In that case a larger animal, such as the rabbit, would be preferable.

that are connected with the intestine (*pyloric* end) and with the esophagus, or gullet (*cardiac* end). Note the covering of blood vessels.

In the fold of the intestine (*duodenum*) next to the stomach, locate the fatty-looking *pancreas*. Find its *duct* and trace its connection with the duodenum.

Press forward the liver and, on its posterior surface, find the *bile sac*. Locate the connection of this with the two lobes of the liver (the *hepatic ducts*). Open this sac and, with the probe, find its connection (the *bile duct*) with the pancreatic duct and the duodenum. Note that the bile duct and the pancreatic duct fuse and enter the duodenum by a common duct.

Examine the membrane (*mesentery*) which supports the intestine. Note its blood vessels. Carefully unravel the intestine (Caution! do not break it) from the stomach to the anus. Determine the relative lengths of the small and the large intestine and the method of their joining. (This connection is guarded by a valve which acts in such a way as to prevent matter returning from the large to the small intestine.)

Slit the stomach just below the gullet entrance and, with the probe, find its connection with the mouth. Above the liver and the stomach, find the muscular partition (*diaphragm*) separating the abdominal from the thoracic cavity.

Illustrate, by a diagrammatic drawing, the connections of the following parts: mouth, gullet, stomach, liver, pancreas, small intestine, large intestine.

Carefully remove the stomach, liver, pancreas, and intestines, and preserve the rest of the animal for further dissection in 85 % alcohol or 4 % formalin.

XXXVII. — The Teeth

Apparatus. — A hand mirror, a molar tooth sawed in vertical sections, an apple.

Directions. — *A. Kinds of Teeth.* With the aid of the mirror and the finger count the number of teeth on each jaw. Is the number the same? Note that they may be divided

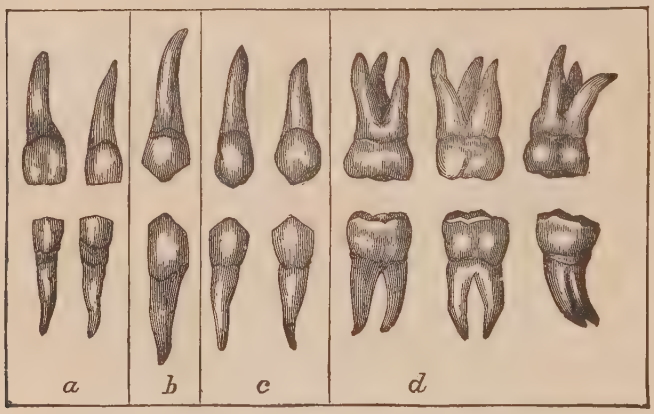

Fig. 28. — *a*, incisors; *b*, canines; *c*, premolars; *d*, molars.

into four classes according to shape. How many broad teeth (*incisors*) have you in the front of each jaw? How many with one point on the surface (*canines*)? How many with two surface points (*bicuspids* or *premolars*)? with more than two surface points (*molars*)? Tabulate these numbers as follows:

	Upper Jaw	Lower Jaw
Incisors		
Canines		
Premolars		
Molars		
Grand Total		

Examine the mouths of animals, such as the squirrel or rat, the cat or dog, and the horse or cow. How do they differ as to the kind and number of their teeth? What kind of food does each animal eat? Which kind of food requires the most chewing? Do you see any connection between the food and the kind of teeth which predominates in each animal?

B. Structure of a Tooth. Draw a section of a molar tooth. Find the following parts: the crown, the neck, roots or fangs, the covering of the crown (*enamel*), the covering of the fangs (*cement*), the central or *pulp cavity* with nerve and blood-vessel aperture, the middle layer (*dentine*). Label all these parts in your drawing. Examine, if possible, the jaw of a human skeleton to show the insertion of the teeth in it.

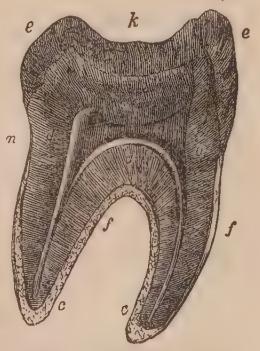

FIG. 29. — A Molar: *k*, crown; *n*, neck; *f*, fangs; *e*, enamel; *d*, dentine enclosing the pulp cavity; *c*, cement.

C. The Use of the Teeth. Bite off a piece of apple and chew it. Answer the following questions: Which teeth are used in the biting off of the apple? which to chew it into small pieces? How are these latter best adapted to break up the food? Of what advantage is it that a horse's molars are ridged on the surface? Could you tell from the examination of the teeth the kind of food an animal eats?

When a tooth decays what part actually decays? What is the difference in the functions of the enamel and of the dentine? How does the location of the nerves in the pulp cavity protect them? Why is a decayed tooth apt to ache?

XXXVIII. — Preparation of Digestion Fluids (Optional)

A. Collection of Saliva. With aid of a piece of paraffin to chew, stimulate the flow of saliva and collect in a small beaker as fast as it forms. Filter this through a wetted filter paper and use the filtrate. The saliva should give no test with Fehling's or Benedict's solution.

B. Artificial Gastric Juice. Obtain a pig's stomach. Cut it open and wash its contents out by gently flushing it with water. Remove the mucous membrane from the cardiac end, and after drying this with filter paper mince it and bottle with four or five ounces of glycerine. (The glycerine dissolves the pepsinogen.) After three days filter through muslin. The filtered solution may be kept indefinitely. When required for use add 0.2 % hydrochloric acid in the ratio of 10 parts of the acid to 1 part of glycerine solution. This acid converts the pepsinogen to pepsin.[1]

A substitute for the above is solid pepsin powder dissolved in water. For use, this should be treated with 0.2 % hydrochloric acid in the same way as the glycerine solution.

C. Artificial Pancreatic Juice. Obtain sheep pancreas. Remove all lumps of fat and mince the pancreas thoroughly. Next grind the minced mass with a little sand and water in a mortar, until it is in the form of a thin paste. Pour this paste into a bottle and add 150 c.c. of 30 % alcohol. Shake repeatedly and let stand for 24 hours. At the end of that time strain the extract through cheesecloth and then filter through wet filter papers. For use add to 1 volume of the alcohol extract 2 volumes of 0.5 % sodium carbonate solution.

[1] If required for use at once, the membrane may be extracted with 0.2 % HCl directly, without the use of the glycerine.

A substitute for this solution may be made by dissolving the solid pancreatin powder in water. For fat digestion add to this the sodium carbonate solution in the same way as to the pancreas solution.

D. Bile. Open and extract the contents of an ox gall or dissolve prepared ox gall in water.

E. Temperature Conditions. To obtain the best results in all artificial digestion experiments keep the materials used as nearly as possible at a constant temperature. For this purpose it is suggested that a constant-temperature water bath be used, if possible. If this is unavailable, an ordinary drying oven may be used with an Argand burner. Another substitute is a deep agate dish, — such as is used in cookery, — with the Argand burner. Place in test tubes the fluids and materials to be digested. Cover the top of the agate dish with a wooden cover having holes bored to fit the test tubes, and suspend the tubes in these. Fill the dish half full of water and heat it to the temperature desired. Adjust the Argand burner to maintain just that temperature.

XXXIX. — Salivary Digestion

Apparatus. — A little salt, dry cracker, dilute starch paste, white of egg, olive oil, saliva, litmus paper, Fehling's solution, concentrated hydrochloric acid, test tubes, constant-temperature apparatus, dialyzer.

Directions. — *A. General Functions of Saliva.* Clear the mouth of saliva by swallowing, and wipe dry the top of the tongue. Place on the tongue a bit of salt. Can you taste the salt? Close the mouth, letting the salt stay on the tongue. What happens in the mouth? Where does the

saliva come from in the mouth? Where is it made? Was the presence of the salt on the tongue sufficient to cause its flow? What does it do to the salt? Can you taste the salt now? Do you think the effect would be the same if the salt had been dissolved in water? Verify by placing a drop of salt water on the dry tongue. Name two functions of saliva that this experiment shows.

Again clear the mouth of saliva, wipe the tongue dry, and place on it some powdered cracker. Try to swallow the cracker. Is it easily done? With the tongue moisten the cracker with saliva and try to swallow. Is swallowing easy now? What is another function of saliva?

Chew some of the cracker slowly and note if any change takes place in its taste. Place on the dry tongue some cracker moistened with water. Is the taste the same? What power has the saliva that is not due to its liquid quality only? (This last power of the saliva is called its chemical power as distinguished from its purely mechanical properties.)

B. Enzyme Action of Saliva. Collect and filter saliva as described in *A* of Ex XXXVIII. Prepare a little thin starch paste. Test a sample of the saliva and the starch paste with Benedict's or Fehling's solution. If no grape sugar is indicated they are ready for use. Next add 1 c.c. of saliva to 5 c.c. starch paste in a test tube and put in a water bath at a temperature of 36° Centigrade. At intervals of 10 minutes test the mixture with Benedict's or Fehling's solution. Results? What has the saliva done to the starch? What caused the change in taste of the cracker in the mouth?

C. Conditions Affecting Salivary Digestion. Place in each of four test tubes 5 c.c. thin starch paste. Add a cubic

centimeter of clear saliva to each, and label them Tubes 1, 2, 3, 4. Pack Tube 2 in ice, boil the contents of Tube 3. Add a few drops of concentrated hydrochloric acid to the fourth tube. In a fifth tube place 1 c.c. of saliva and a little minced white of egg, and label it "Tube 5." In a sixth tube place 1 c.c. of saliva and a few drops of olive oil. Label it "Tube 6." Shake each tube.

Tube 1. Test the mixture with litmus paper. Is it acid or alkaline? Now heat it gently to a temperature of 36° C. Keep it at this temperature for twenty minutes and then test with Fehling's solution. What has the saliva done to the starch?

Tube 2. After the second tube has been in ice twenty minutes, test with Fehling's solution. What is the effect of cold on the action of saliva?

Tube 3. Keep the third tube at room temperature twenty minutes and test as above. Note result. Let stand twenty minutes longer at 36° C. and then test again with Fehling's solution. Result? What has the boiling done to the saliva?

Tube 4. Heat the fourth tube to 36° C. for twenty minutes and then test as above. Does the Fehling's solution give any test for sugar? Reason?

Tube 5. Heat the fifth tube to 36° C. for twenty minutes and then test with Fehling's solution. Does saliva convert white of egg to sugar?

Tube 6. Treat Tube 6 in the same way as Tube 5. Does saliva change olive oil to sugar?

Tabulate conditions favorable and unfavorable to salivary digestion.

D. Relation of Salivary Digestion to Osmosis. In each of two dialyzers place 20 c.c. thin starch paste. To one add

2 c.c. saliva. Surround each dialyzer with water, and at the end of 24 hours test the water with Fehling's or Benedict's solution, and with iodine solution. Does starch osmose? Does grape sugar? What advantage results to the body from the salivary digestion of starch?

XL. — Peptic Digestion

Apparatus. — Glycerine solution of pepsin or solid pepsin dissolved in water, 0.2 % hydrochloric acid, concentrated hydrochloric acid, caustic soda, alcohol, minced white of egg, starch, beef fat, milk, test tubes, constant-temperature apparatus, biuret reagent, Millon's reagent.

Directions. — *A. Action of Artificial Gastric Juice on a Protein.* To a small piece of white of egg in a test tube add 10 c.c. of artificial gastric juice prepared as described in Ex. XXXVIII, *B.* Place in a temperature of 36° C. and examine at intervals of 10 minutes. Describe the changes you observe. Test the final product with biuret reagent. Is it protein? Boil it. Does it coagulate? State in your own words what the gastric juice has done to the white of egg.

B. Conditions affecting Gastric Digestion. Label seven test tubes, — Tube 1, Tube 2, etc., — and prepare them as follows: In the first tube place 5 c.c. of the glycerine solution or dissolved pepsin and dilute with 10 c.c. of water. In the second put 15 c.c. of the 0.2 % hydrochloric acid. In the third, fourth, and fifth tubes place 15 c.c. of glycerine solution which has been diluted previously with ten parts of 0.2 % hydrochloric acid to one of glycerine solution. Prepare the sixth tube in the same way as the third and then add 5 c.c. of concentrated hydrochloric acid. Prepare the seventh tube

in the same way as the third and then add 5 c.c. of caustic soda solution. Add to each of the seven tubes some minced white of egg, and shake it. Place Tubes 1, 2, 3, 6, and 7 in a temperature of 36° C. and keep at this temperature for twenty-four hours. Place Tube 4 in ice. Boil the contents of Tube 5, cool it and then keep it at 36° C. for 24 hours.

At the end of twenty-four hours describe the appearance of all the tubes. Does pepsin alone digest protein? What does 0.2 % hydrochloric acid alone do to protein? Why are both present in the stomach? What effect does cold have on gastric digestion? Why is much ice water bad for digestion? What does boiling do to gastric juice? What is the effect of strong acid? strong base? Why is sodium bicarbonate given in cases of sour stomach? Can saliva act on starch in the stomach?[1] Reason?

C. Effect of Gastric Juice on Other Nutrients. Prepare three tubes and add to each 10 c.c. of artificial gastric juice. To tube 1 add a piece of white of egg (control). To tube 2 add a piece of beef fat. To tube 3 add a little starch. Place at 36° C. for 24 hours. At the end of that time examine. Does gastric juice digest fat? starch?

D. Effect of Gastric Juice on Milk. To 10 c.c. of milk in a test tube add an equal volume of artificial gastric juice. What happens to the milk? Remove some of the solid particles and test with Millon's reagent. Are they protein? Let stand 24 hours at 36° C. Do the particles digest? Why is milk a good food? Save some of the particles for Ex. XLI.

[1] Owing to the slow mixing of the gastric juice with food in the stomach salivary digestion may continue there from 20 minutes to 40 minutes after the food is swallowed.

XLI. — Pancreatic Digestion

Apparatus. — Alcohol extract pancreas or solution of pancreatin, 0.5 % sodium carbonate solution, minced white of egg, biuret reagent, starch paste, milk, blue litmus solution, 0.2 % HCl, KOH solution, concentrated HCl, test tubes, constant-temperature apparatus.

Directions. — *A. Action of Pancreatic Juice on Protein.* To a piece of minced white of egg in a test tube add 10 c.c. artificial pancreatic juice (1 volume alcoholic extract + 2 volumes 0.5 sodium carbonate solution, see Ex. XXXVIII). Place in a temperature of 36° C. and examine at intervals of 10 minutes. Describe the changes you observe and compare with the effects noted in Ex. XL, *A*. Does the white of egg swell? Test the final product with the biuret reagent. Is it protein? Repeat the above experiment, using the particles of milk curd obtained in Ex. XL, *D*. Do they digest?

B. Action of Pancreatic Juice in Starch. To a little starch paste in a test tube add 10 c.c. artificial pancreatic juice. Place in a temperature of 36° C. and test portions with Benedict's or Fehling's solution at intervals of 10 minutes. Describe the results. Does pancreatic juice digest starch?

C. Action of Pancreatic Juice on Fat. To about 20 c.c. of milk add sufficient blue litmus solution to impart a deep blue color to the milk. Divide the milk into two equal portions and transfer these to test tubes. To one half add 5 c.c. of *boiled* pancreatic juice (control) and to the other add 5 c.c *unboiled* pancreatic juice. Shake each mixture thoroughly and keep at 36° C. for a laboratory period. At the end of the time describe any changes that you observe. What does pancreatic juice do to milk fat?

D. Conditions Affecting Pancreatic Digestion.[1] Prepare seven test tubes and into each pour 3 c.c. of alcoholic extract pancreas and 2 c.c. of water. To these solutions add successively (*a*) 5 c.c. H_2O; (*b*) 5 c.c. 0.2 % HCl; (*c*), (*d*), (*e*) 5 c.c. 0.5 % Na_2CO_3; (*f*) 5 c.c. concentrated KOH solution; (*g*) 5 c.c. concentrated HCl. Drop into each a piece of minced white of egg. Place tubes (*a*), (*b*), (*c*), (*f*), and (*g*) in a temperature of 36° C. Pack tube (*d*) in ice. Boil the contents of tube (*e*) and then place at 36° C. Tabulate the results at the end of an hour. Write a statement giving the conditions favorable and unfavorable to pancreatic digestion based upon your results.

XLII. — Study of Digestive Action of Bile

Apparatus. — Ox bile, milk, test tubes, pancreatic juice, blue litmus solution, constant-temperature apparatus.

Directions. — Prepare four test tubes as follows: Into each put 10 c.c. fresh milk. Add to tube 1, 10 c.c. of water. To tube 2 add 5 c.c. of bile and 5 c.c. of water. To tube 3 add 5 c.c. of bile and 5 c.c. pancreatic juice. To tube 4 add 5 c.c. pancreatic juice and 5 c.c. water. Shake well and place the four tubes at 36° C. after coloring each blue with the litmus solution. Let stand and note results. Does bile alone digest milk fat? Does bile hinder or help the pancreatic digestion of milk fat?

Let tubes 1 and 2 stand for several days. Does bile prevent the putrefaction of milk?

State your conclusions as to the digestive power of bile as observed in the above results.

[1] This experiment may be repeated with starch paste or protein if desired, using the same method described for milk.

XLIII. — Microscopic Anatomy of the Digestive Tract (Optional)

Apparatus. — Prepared slides of the cross sections of the walls of the esophagus (middle part), stomach (pyloric section), small intestine (injected blood vessels); compound microscope.

Directions. — Make drawings of each section studied and label the parts. See Figs. 30 and 31.

Fig. 30. — Vertical Section of the Coats of the Stomach; *d*, surface of mucous membrane, and mouths of gastric follicles; *m*, gastric tubuli, or follicles; *mm*, dense, connective tissue; *sm*, sub-mucous tissue; *cm*, transverse muscular fibers; *lm*, longitudinal muscular fibers; *s*, fibrous, or serous, coat.

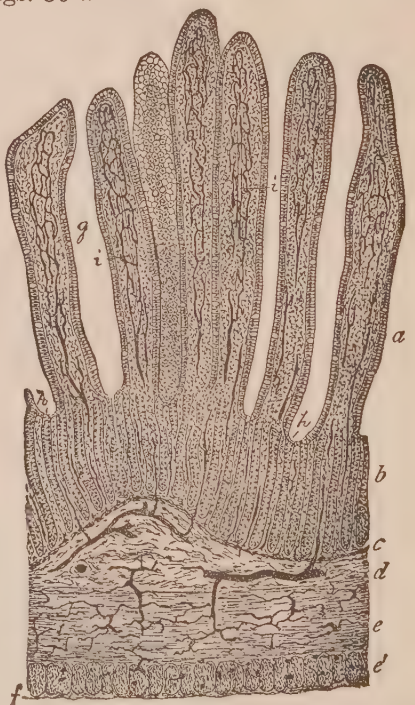

Fig. 31. — Section of Injected Small Intestine of Cat: *a*, *b*, mucosa: *g*, villi; *i*, their absorbent vessels; *h*, simple follicles; *c*, muscularis mucosæ; *d*, sub-mucosa; *e*, *e'*, circular and longitudinal layers of muscle; *f*, fibrous coat. All the dark lines represent blood vessels filled with an injection mass.

XLIV. — Tabulation of Nutrient Digestion (Optional)

Directions. — Fill out the following table from the results obtained in the preceding exercises. If a given nutrient is digested by more than one reagent, indicate it by separate entries for each in the table.

Nutrient	Region of Alimentary Tract Digested in	Digestive Reagent	Name of Digested Product
Protein			
Protein			
Starch			
Starch			
Fats			
Fats			

BLOOD

XLV. — General Properties of Blood

Apparatus. — Glass slides and cover glasses, magnifier, microscope, needle, physiological salt solution (0.6 % solution), neutral carminate of ammonia.

Directions. — Wind a handkerchief tightly around the thumb, just below the joint. Now bend the upper joint. The blood will collect on the top of the thumb just below the nail. Sterilize a needle by holding it a second in a flame, and prick the thumb just below the nail. The blood from the puncture may be easily and quickly transferred to a glass slide.

A. With a magnifier examine a drop mounted as above. Is it all liquid? Is it the same color throughout? Describe the color at the edge of the drop. Let the drop remain on the slide for ten minutes and examine again. Is it liquid now? Prick at it with the needle point and describe its consistency. This formation is called a *clot*. Examine the puncture on the thumb with the magnifier. Has it stopped bleeding? What is the condition of the blood on the surface of the puncture? Does it resemble the condition of the drop on the slide? Bind up the thumb as before and flex the upper joint. Does the puncture bleed again? Wash off the clot with water. Does the bleeding begin again now? What is the advantage of this clotting action of the blood?

B. Mount a drop of blood quickly, and examine at once with the high power of the microscope. Note the *rouleaux* of *colored corpuscles*. What is their color? Note

also the *white* or *colorless corpuscles* (colorless corpuscles tend to stick to glass; hence they will remain if the cover glass is pressed with a needle so that the current will drive the others aside, and they can then be more readily seen). What is the color of the liquid in which the corpuscles are floating? This liquid is called the *plasma*. Let this preparation stand for fifteen minutes and then run under the cover glass a drop of strong solution of neutral carminate of ammonia.[1] This decolorizes the red corpuscles but brings

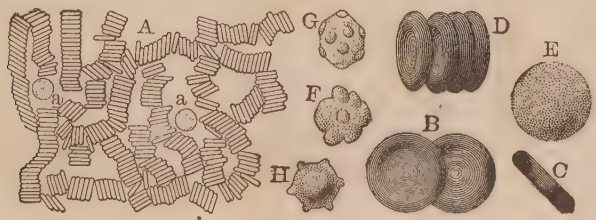

FIG. 32. — Blood Corpuscles: *A*, red corpuscles in *rouleaux; a, a*, colorless corpuscles (× 400); *B*, red corpuscles in focus; *C*, view of edge; *D*, three-quarters view; *E*, red corpuscle swollen with water; *F, G, H*, distorted red corpuscles.

out the nuclei of the white corpuscles and the fibrin filaments. Draw some of the white corpuscles and note the shape of the *fibrin filaments*. Note how the entanglement of these filaments forms the foundation of the clot.

C. Mount a drop of blood as in *B*, but before covering it with the cover glass, add a drop of physiological salt solution. This causes the separation of the red corpuscles. Draw a surface view and an edge view of a red corpuscle under the high power. How do the red corpuscles differ in appearance from the white corpuscles? Have they a nucleus?

[1] A permanent mount may be made of this preparation if a little glycerine is allowed to diffuse under the cover glass and the cover slip is then cemented to the glass with gold size.

XLVI. — Study of Ox or Hog Blood

Apparatus. — Five-ounce bottles, fresh blood, egg beater, test tubes, food-testing materials, constant-temperature apparatus, compound microscope, slides and cover glasses, distilled water, dialyzer.

Directions. — Obtain from a butcher a quart or more of fresh-drawn blood. Divide this among the five-ounce bottles as follows:

Bottle 1. Fill with fresh blood and cork so as to exclude all air.

Bottle 2. Fill two-thirds full and leave uncorked.

Bottles 3, 4, and 5. Fill two-thirds full and cork.

Place the remainder of the blood in a basin and whip vigorously with an egg beater or twigs. Take off the stringy substance that collects on the beater, and wash it in water until it has lost its red color. Put it in Bottle 6 and add to it a little water.

Pour the whipped blood into a suitable-sized bottle and label it "Bottle 7." Leave uncorked.

A. Study of Coagulation or Clotting. Place Bottles 1 and 2 in ordinary room temperature. Examine frequently for several days. In which bottle does the clot form quickest? Does the absence of air in Bottle 1 have any effect on the rate of clotting?

Place Bottle 3 in a constant temperature of 36° C. and pack Bottle 4 in ice. In which does the clot form quickest? Does temperature affect the rate of clotting?

Place Bottle 5 under the same conditions as 1 and 2 but shake from time to time. Does this affect the rate of clotting?

Place Bottle 7 with 1, 2, and 5. Examine after three days. Has this blood clotted? What is missing in it? (The substance is called *fibrin*.)

Summarize the conditions best suited to clotting.

B. Study of the Clot. Pour off the liquid from all the bottles in which a clot has formed and place it in Bottle 8. (This liquid is called *serum.*) Then break one of the bottles containing a clot and remove the clot entire. What is its shape? color? consistency? Cut off a thin slice of it and examine it under the microscope. What parts can you distinguish? Does it contain any corpuscles? The jelly-like substance is to be found in its pure state in Bottle 6. Examine some of this fibrin. What is its color? Test it for protein. What is the result? Explain in a few words the formation of a clot and the part played in its formation by the fibrin and the corpuscles.

C. Study of the Serum. Examine the liquid in Bottle 8. What is its color? Why is it not red?

Test a little with iodine solution for starch. Since starch must be digested before it can be absorbed into blood, why should you expect this result?

Test some of the serum with Benedict's or Fehling's solution for the presence of grape sugar. Do you get a strong test? What does this result suggest as to the amount present?

Burn a little serum on a piece of platinum foil. Does it contain any mineral matter?

Place a drop on a piece of unglazed paper and let it evaporate. Does it leave a grease spot?

Heat a little serum and test for proteid. Can fibrin be present? Explain the result of the test. What use is made of the nutrients present in serum? How do they get into the serum? What function of the blood does the presence of these nutrients suggest?

D. Study of Defibrinated Blood. Examine the contents

of Bottle 7. How does this blood differ from fresh blood? from serum?

Place some of this blood in the dialyzer. Fill the outer jar with distilled water. Does the color of the water in the outer jar change? After a time test the water in the outer jar for protein, grape sugar, minerals. What part of the blood osmoses?

Fill a bottle half full of defibrinated blood and shake it vigorously. Does it change in color? What was mixed with the blood by shaking the bottle?

XLVII. — Crystallization of Hæmoglobin from Blood (Optional)

Apparatus. — Defibrinated blood, microscope slide, cover glass, compound microscope.

Directions. — To one drop of defibrinated blood on a slide add one drop of water. Mix the two drops thoroughly, but use care not to spread them. Allow the mixed drops to dry in the air until a comparatively wide dry border is formed. Cover with cover glass and look for crystals of hæmoglobin with the compound microscope.

XLVIII. — Detection of Blood in Blood Stains (Optional)

Apparatus. — Blood-stained cloth, evaporating dish, compound microscope slides and cover glasses, solid sodium chloride, lamp, glacial acetic acid.

Directions. — *A.* Spread the cloth in an evaporating dish and moisten thoroughly with water. Squeeze the water out into the dish. Then examine a drop of this liquid with the microscope for blood corpuscles.

B. Hæmin Test (*Teichman's*). Place a drop of the cloth

extract on a microscope slide. On a second slide place a drop of blood obtained as described in Ex. XLV (control). To each drop add a minute grain of sodium chloride and carefully evaporate to dryness over a low flame. Put a cover glass in place, and run under it a drop of glacial acetic acid. Warm gently until gas bubbles form. Add now another drop of the acetic acid, cool the preparation, examine under the microscope, and describe the crystals (hæmin crystals) which form. Would this be an absolute test for blood? for human blood?

CIRCULATION AND THE BLOOD SYSTEM

XLIX. — Properties and Location of Arteries and Veins

Apparatus. — A watch with a second hand, a needle, a chemical thermometer.

Directions. — Examine the back of the hand and wrist and locate the dark-colored veins. Is the blood this color? Place your finger on a vein. Can you feel any motion? Is there any difference in the size and prominence of the veins when you exercise violently? Why should you expect this result?

Find your pulse on the palm side of the wrist. Count its beats and record the number per minute. Test this rate at various times of the day. Is it uniform at all times? Test your body temperature at the same time by placing the bulb of the chemical thermometer under the tongue. Does the temperature vary with the pulse rate? Does either increase after violent exercise? If food is burned up by exercise, and blood contains oxygen and food, how do you account for these effects?

Examine other parts of the body for veins and arteries (pulse always indicates the presence of an artery). Which are most numerous on the surface? Which are best protected? The bleeding of a cut artery is much more difficult to stop than that of a vein, owing to its pulsation.

Examine the skin on the back of the hand between two veins. Can you see any blood vessels? Place the finger

on this part. Can you feel any pulse? Prick through the skin at this point with a sterilized needle. Does the puncture bleed by spurts or steadily? The small blood vessels filling these places are called *capillaries* on account of their small size (*capillus* = a hair). They connect the veins and arteries.

L. — Circulation in a Frog's Foot

Apparatus. — Compound microscope, cover slip, live frog, shingle, wet absorbent cotton, and cloth.

Directions. — Bind a live frog in wet absorbent cotton, leaving one leg extended. Fasten the frog, so bound in place,

Fig. 33. — Capillary Circulation in the Web of a Frog's Foot, × 100: *a*, *b*, small veins; *d*, capillaries in which the corpuscles are seen to follow one another in single series; *c*, pigment cells in the skin.

on a frog board (a piece of shingle with a hole the size of a cover slip at one end). Stretch the web of the foot over the hole in the board. Fasten it securely, with the stretched web as level as possible. Mount this board on the microscope stage in such a way as to bring the web-covered hole under the objective of the microscope. With a pipette place a drop of water on the top of the web, and cover with a piece of cover slip. Illuminate in the usual way and focus first with the low and then with the high power.

Note the network of blood vessels and the slow-moving stream of corpuscles within them. Are the corpuscles the same size and shape as those in the human blood? Is there only one kind? Observe that in some of the blood vessels the blood moves in spurts at regular intervals. What kind of vessels are these? Does the blood in these flow from or toward the body? Follow the course of the blood from these into the smaller tubes where the corpuscles move in almost single file. Do these show pulsations? Trace the flow from these into larger vessels where no pulsation is evident. Note the direction of flow in these tubes. What is the name of these tubes? Define *artery*, *vein*, and *capillary* in terms of the direction of blood flow.

LI. — Minute Structure of Arteries and Veins (Optional)

Apparatus. — Prepared slides of cross sections of arteries and veins, compound microscope.

Directions. — Note that both artery and vein have three coats: a lining of epithelial cells called here *endothelium*, a middle layer consisting of a mixture of muscle and elastic fibers, and the outside layer or coat of connective tissue

bundles. Make careful drawings of the two preparations, showing the location and form of these layers, and label the above-mentioned parts. In which of the two forms of blood vessels is the elastic and muscular coat thickest? Why should you expect this condition from the method of flow of blood in each? What is the special advantage of the elastic fibers in the artery? In what way do they aid to keep the capillaries filled at the end of an artery pulsation? Is the pressure greatest in arteries or in veins?

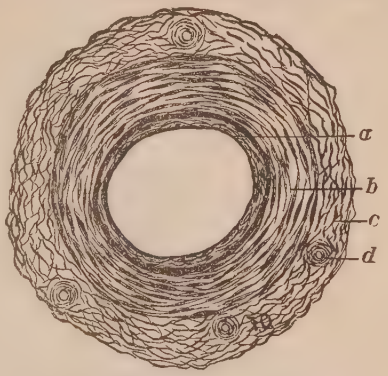

FIG. 34. — Cross Section of an Artery: *a*, endothelium; *b*, muscular layer; *c*, connective tissue; *d*, small artery to nourish large one.

LII. — STRUCTURE OF THE HEART

Apparatus. — Sheep's heart from the butcher with pericardium attached, bristle seekers, dissecting instruments.

Directions. — Locate the parts named below, and make drawings to show their position.

A. Note that the heart moves easily inside a loose sac. Cut this *pericardium* open and observe its slippery inner coat. Note a similar coat on the outside of the heart. What lies between these two coats? This liquid and the slippery coats prevent friction when the heart pulses.

B. Carefully cut away the pericardium from the blood vessels, and the fat from the surface of the heart. Locate the *aorta*, *venæ cavæ*, *pulmonary veins* and *artery*, and push bristle seekers through these blood vessels into the heart.

C. Examine the outside of the heart and locate the following parts of the heart proper: *right* and *left auricles, right* and

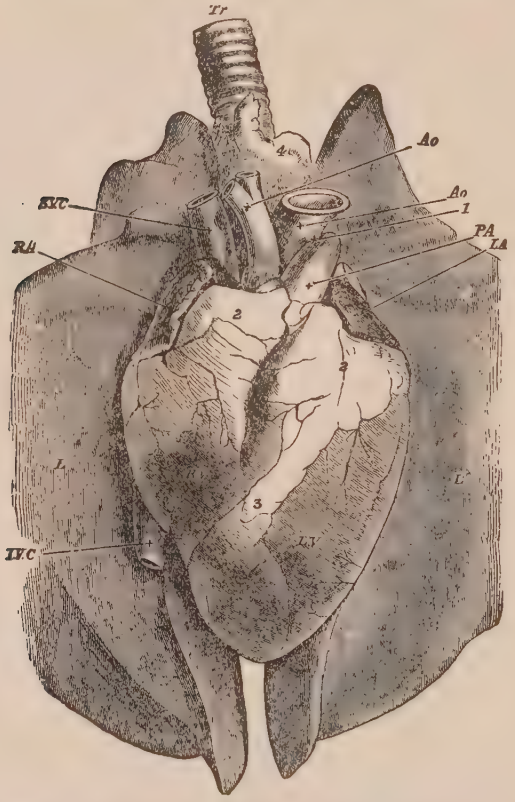

FIG. 35. — Heart in position with pericardium removed (Human): *Tr*, trachea; *L*, lungs; *RA*, *LA*, right and left auricles; *RV*, *LV*, right and left ventricles; *Ao*, aorta (two branches); *SVC*, *IVC*, superior and inferior venæ cavæ; *PA*, pulmonary artery.

left ventricles. By right and left are meant the parts of the heart that are right and left in regard to the position of the heart in the body. Which parts have the thickest walls?

The walls are made of muscle, and these thick-walled parts do the pumping.

D. Cut off carefully the front walls of the right auricle and ventricle. By means of the bristles locate the entrance

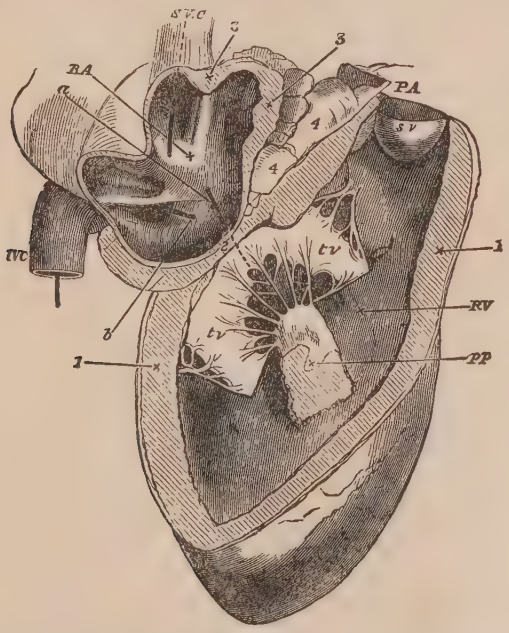

Fig. 36. — Right Auricle and Ventricle (Sheep): *RA*, *RV*, right auricle and ventricle; *IVC*, *SVC*, inferior and superior venæ cavæ; *a*, *b*, bristle seekers showing connections between auricle and ventricle, auricle and vena cava; *PA*, pulmonary artery; *tv*, tricuspid valve; *pp*, papillary muscle; *sv*, semilunar valves.

into the auricle of the *inferior* and *superior venæ cavæ*, and the entrance into the ventricle of the *pulmonary artery*. Find the connection between the auricle and the ventricle and note the *tricuspid valve* that closes this entrance. Locate also the *chordæ tendinæ* that attach this valve to the *papillary muscles* on the surface of the heart. What is the effect

of the contraction of the ventricle on the action of this valve? Note finally the *semilunar valves* at the entrance to

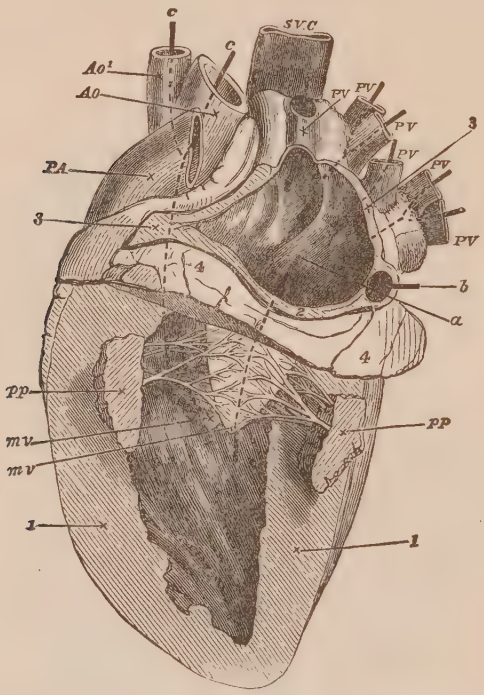

FIG. 37, — Left Auricle and Ventricle (Sheep); *a*, *b*, *c*, Bristle seekers showing connections of auricle with ventricle, of auricle with veins, and of ventricle with arteries; *PV*, pulmonary veins; *pp*, papillary muscles; *mv*, mitral valve; *PA*, pulmonary artery; *Ao*, aorta; *SVC*, superior vena cava.

the pulmonary artery. How does their arrangement prevent the backward flow of blood into the heart?

E. Cut off the front walls of the left auricle and ventricle in the same way. Have they any connection with the right side of the heart? Locate, with the aid of the bristles, the

entrance of the *pulmonary veins*. How many enter the auricle? Find the entrance from the auricle to the ventricle, and the *mitral valve* which guards this entrance. Does it show chordæ tendinæ and papillary muscle attachments? How does it differ in shape from the tricuspid? Locate the *semilunar valves* at the entrance of the aorta.

Make a careful diagram of the course of circulation through the heart to the lungs and back to the heart and body.

THE BODY SKELETON

LIII. — Study of the Skeleton

Apparatus. — Human skeleton.

Directions. — Tabulate as follows the various classes of bones:

Kind of Bone	No.	Name of Bone	Location in Body	Function

LIV. — Gross Structure of Bones

Apparatus. — Fresh rib, thigh bone, and dorsal vertebra; saw, needle.

Directions. — *A. The Rib*, a flat bone. Draw the bone from the flat side. What is found at the ends of the bone? What is the color, consistency, and function of this substance? Bend the bone. Is it flexible? Pick off the membrane (*periosteum*) that covers the bone. Does it separate easily from the bone? Does it tear easily? Are all parts of the bone protected by this covering?

Saw the rib across. Examine the section and draw it, labeling the parts in the order in which they occur. What part is periosteum? hard bone? spongy bone? marrow? Examine the central marrow. What is its color? How

does it feel? Heat some in water in a tube. What collects on the top of the water?

B. The Thigh Bone, or Shank, a long bone. Draw the bone, and shade with different colors the parts that are covered with cartilage and with periosteum. What is the function of the enlarged heads of this bone? Of what advantage is it that they are irregular in surface?

Saw the bone lengthwise, draw, and label the parts. In what portion of the bone is the marrow most plentiful? Is the shaft solid? What is the advantage of this condition?

C. The Dorsal Vertebra. Draw a dorsal vertebra from the side and from the top. With the aid of the diagram locate the following parts: The body of the vertebra, spinous process, transverse processes, spinal cavity, rib articulations, vertebral articulations. How are the articulations protected? What is the function of the processes?

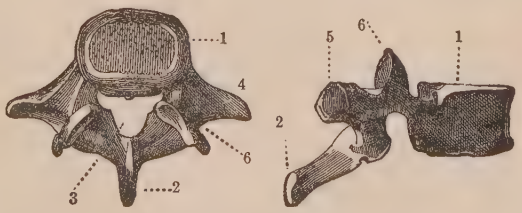

Fig. 38.— Thigh Bone, in Longitudinal Section.

Fig. 39.— A Dorsal Vertebra: 1, centrum or body; 2, spinous process; 3, spinal cavity; 4, transverse process; 5, rib articulation; 6, vertebral articulation.

LV. — Composition of Bone (Optional)

Apparatus. — Two clean ribs, a soup bone split in two, 20 % hydrochloric acid, bottle big enough to hold rib, evaporating dish, food-testing materials, Bunsen burner.

Directions. — *A.* Place one of the ribs in the bottle and fill the bottle with the 20 % hydrochloric acid. Let it stand for a few days. At the end of that time examine it. Has it changed in shape? Take it out of the bottle and bend it. What power has it lost? What substance is left? Hold a little of it in the flame. Does it burn? Pour a little of the acid from the bottle into the evaporating dish and evaporate to dryness. What kind of substance is left? What material did the acid dissolve out of the bone?

B. Burn the other rib. What is the shape of the part that is left? Is it flexible? Put some of it in the acid. Does it dissolve? Name the two main constituents of bone.

C. Cover the split soup bone with water and gradually bring to a boil. Strain off the liquid and let it cool. What do you find floating on the surface? What forms as it cools? What is the character of this substance? Test for nutrients.

LVI. — Structure of a Joint

Apparatus. — Fresh leg joint of lamb or veal, scalpel.

Directions. — Examine the tissue that binds the two bones together. What is the character of these bands, or *ligaments?* Are they flexible? How do they control the direction of movement of the bones? Cut off the ligaments with a scalpel. Note the liquid found within. What does it look like? (It is a lubricant called *synovial fluid.*)

Examine the ends of the bones. With what are they

covered? Press this surface. Is it elastic? What is the advantage of this? Is the surface smooth? Of what ad-

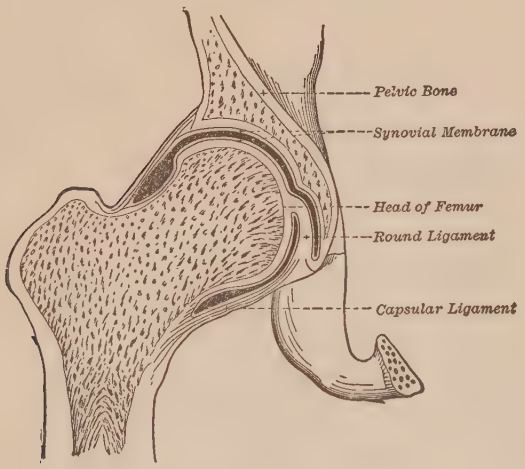

Fig. 40. — A Joint.

vantage is this? What is the reason for the enlarged ends of the bones? for their irregular surfaces?

LVII. — Forms of Joints

Apparatus. — The human skeleton.

Directions. — Examine the following joints and describe the range of motion of each: Knee, elbow, vertebral, shoulder, hip, jaw, head, and spine, bones of the skull, ribs.

Name the bones united in each case and classify the joints under the following names: hinge, ball and socket, gliding, rotary, dovetail, symphysis.

Which of the above are movable joints? fixed?

MUSCLES AND MOTION

LVIII. — Dissection of the Muscles

Apparatus. – The body of the rat used in Ex. XXXVI (any other animal will serve the purpose, and if a demonstration is desired for the study of the leg muscles the leg of a sheep may be substituted), scalpel.

Directions. — Carefully cut off the hind leg of the rat, close to the hip joint, and remove the skin. Note the muscles covering the bones and the glistening white muscle sheath (*perimysium*) covering each muscle. At the ends of the muscles note the white *tendons*. Are the muscles attached directly to the bones? The end of the muscle that moves most in contraction is called its *insertion;* the one that moves least, its *origin*. Where are the tendons most numerous? How does this arrangement avoid clumsiness in the foot? Compare with the arrangement in your own hand and foot. Is it the same?

Separate the muscles without cutting them, and pull on each to determine what part of the leg it controls. Muscles that extend a joint are called *extensors*, those that bend it are called *flexors*. Note that all these muscles have a thick center, or belly, and tapering ends with tendons attached at the ends. Those muscles with two tendons at the origin are called *biceps;* those with three, *triceps*. Examine one of these tendons. How is it different from a muscle? Is it elastic? Why should you expect this from its use?

Remove the skin from the sides of the body. How do

the underlying muscles differ from the leg muscles? Have they tendinous ends? What two classes of muscles based upon their form can you name from your study? Mention some other parts of the body where the different kinds of muscles can be found.

Preserve the rest of the rat's body for future use.

LIX. — Gross Structure of Muscle

Apparatus. — A bellied muscle from the rat or frog (a piece of fresh beef will serve), needles, compound microscope and slides, food-testing materials.

Directions. — Boil the muscle in water for a few moments and pick it to pieces with the needles. Note that it separates easily into bundles. Why is cooked beef more easily chewed than raw? Examine the perimysium covering the bundles. What sort of tissue is it? Describe its appearance. What purpose does it serve? Place one of these bundles in a drop of water on a slide and with the needles tear off the perimysium and tease the bundle into fibers. Examine one of these fibers under the low power of the microscope. Note its covering (*sarcolemma*) and its striated appearance. All muscles under direct nerve control (*voluntary muscles*) show this striation. (For the minute anatomy of this fiber see Ex. XXX.)

Apply the xanthoproteic and other nutrient tests to pieces of the muscle. From the strength of the various reactions, what is the main constituent of muscle? Why does an athlete require a diet rich in protein?

LX. — Nerve Muscle Preparation (Optional)

Apparatus. — Put a frog in a bottle or jar, pour in a little chloroform, and cork the bottle. As soon as the frog is still, remove it from the jar and, with a scalpel, sever the spinal cord just back of the skull. With a wire, destroy the brain and spinal cord. Dissect

away a hind leg; remove all the muscles except the gastrocnemius, and separate this at its lower attachment. Fasten the femur strongly in a clamp. With a pointed glass rod separate the sciatic nerve at the upper part; do not touch it with metal instruments. Into the

FIG. 41. — *sc*, sciatic nerve; *g*, gastrocnemius; *ad*, *b*, etc., other muscles.

lower end of the muscle insert a hook and connect it with a lever as in Fig. 42. Connect a copper wire, insulated except at the end which is to be used as an electrode, with each pole of a battery of two dry cells. For convenience a key of some kind may be inserted in the circuit to make and break.

Directions. — Touch the free end of the nerve with the two electrodes. What happens to the muscle? Record the extent of the action. This shows that nerve stimulation may cause the muscle to move. Keeping the electrodes in contact with the nerve, note whether the action continues.

Remove the electrodes. What happens? Repeat this process several times and mark the distance that the lever moves each time. Is it the same? Does the action increase or decrease? This result illustrates what may happen from overstimulation; namely, *muscle fatigue.*

Repeat the experiment, applying the current to the body of the muscle instead of the nerve. Compare with the results of the first experiment as to the extent and strength of the action.

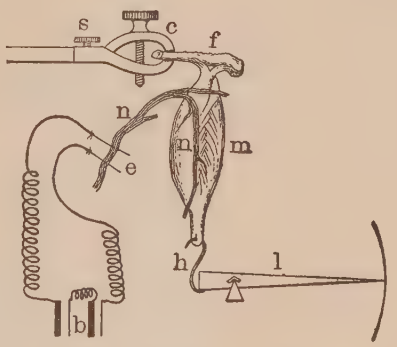

FIG. 42. — Nerve Muscle Preparation: *s*, set screw; *c*, clamp; *f*, femur; *m*, gastrocnemius; *n*, sciatic nerve; *h*, hook; *l*, lever; *e*, electrodes; *b*, battery.

In both of the above experiments what property of the muscle is stimulated? Why is muscle called contractile tissue?

LXI. — STUDY OF LEVER ACTION (OPTIONAL)

Apparatus. — Wooden bar with holes near the ends and at the middle (exactly halfway between the end holes), spring balances.

Directions. — *A.* Support the bar by the middle hole (see Fig. 43, *A*) and trim the bar till it balances level. Fasten the spring balances in the two end holes. Pull down on each, keeping the bar horizontal. Compare the pulls registered by the balances. What is their relation? Attach one balance halfway between the end and middle holes, keeping the second balance in the other end hole. Pull until the bar is level as before. What is the relation of the registered pulls now? Verify the following law by changing the position of the two balances.

Weight × perpendicular distance from the pivot equals pull × perpendicular distance from the pivot. (Perpendicular distance is measured from the pivot at right angles to the direction in which the force is acting.)

This arrangement of lever is called a lever of the first class.

B. Support the bar by one end hole, and at the extreme end attach a weight so that the bar will balance level; then

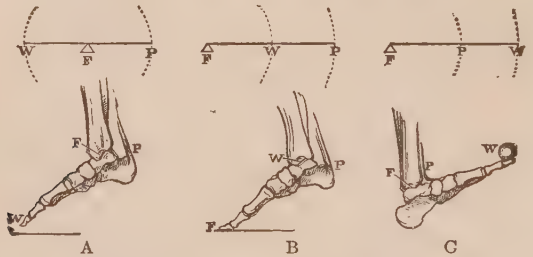

FIG. 43. — Forms of Levers: *A*, 1st class; *B*, 2d class; *C*, 3d class; *W*, weight; *F*, fulcrum or pivot; *P*, pull.

insert the balances in the other two holes (see Fig. 43, *B*). Pull down with the one nearest the pivot (weight), and up with the one at the end (pull). Record the pull and weight when the bar is level, measure the distances from the pivot, and see if the law of *A* still holds. This arrangement is called a lever of the second class.

C. If the pull nearest the pivot be called the *pull* and the other the *weight*, the arrangement is called a lever of the third class (see Fig. 43, *C*).

LXII. — LEVERS OF THE BODY (OPTIONAL)

Directions. — *A.* Locate on the upper arm the biceps muscle, or flexor of the arm. Where is it attached to the forearm and how far (perpendicular distance) from the elbow? Measure the perpendicular distance from the elbow

to the center of the palm. If now we put a weight of ten pounds in the palm and bend the arm, what class of levers is illustrated? How much force is required on the part of the muscle to raise ten pounds' weight? By selecting different weights to lift, determine the maximum strength of the biceps muscle. What muscle is used in striking an outward blow with the fist? Where is it located and inserted? Note that the flexors and extensors in other parts of the body are usually arranged in pairs.

B. Examine the relation of the muscle, weight, and pivot in the following cases, and tell which class of lever each illustrates: Jaw action in chewing, flexing of the fingers, movement of the legs in kicking, bending the body, movement of the foot about the ankle (see Fig. 43).

NOTE. — The instructor can suggest other problems of the above nature to make clear the laws of lever action.

RESPIRATION

LXIII. — Dissection of a Rat's Lungs

Apparatus. — Body of the rat used in Exs. XXXVI and LVII, scalpel, glass tube of one-eighth inch diameter.

Directions. — Remove the skin from the surface of the ribs and throat. Examine carefully the muscles between the ribs (*intercostals*). Seize the base of the breastbone and move it up and down. Notice the motion of the intercostals during this process.

Insert the glass tube in the top of the windpipe through the throat opening, and blow gently through this tube. Observe the motion of the ribs and the motion of the muscular *diaphragm* that forms the partition between the abdominal and the thoracic cavities. Press the diaphragm up with the finger and note that air is forced out of the tube.

Now cut the ribs where they join the breastbone, and press them back to expose the organs of the cavity. Sketch the position of the lungs and heart. Compare with Fig. 35, page 82. Note the texture of the lungs and observe the windpipe (*trachea*) with its cartilage rings. (These are necessary to prevent collapse of the tube.) How is the windpipe connected with the lungs?

Carefully dissect out the lungs and windpipe and float them in water. Cut them at the entrance of the windpipe and trace out the *bronchi* and their branches. How do these branches end? (This large amount of branching allows the

air to be brought in contact with very many small blood vessels, through the walls of which oxygen is absorbed by the blood.)

LXIV. — Mechanics of Respiration

Apparatus. — A glass bell jar open at the top, a glass tube with a toy balloon firmly bound to one end, a stick with a knob, a piece of sheet rubber, a one-holed stopper to fit top of bell jar.

Directions. — Pass the tube through the stopper and seal it in place with wax. Insert the stopper in the top of the bell jar with the balloon inside the jar. Tie the knob into the center of the rubber sheet and fasten the latter tightly across the base of the bell jar, leaving the stick outside to serve as a handle. With this arrangement the tube corresponds to the trachea, the balloon to the lungs, the rubber sheet to the diaphragm, and the jar to the thoracic cavity.

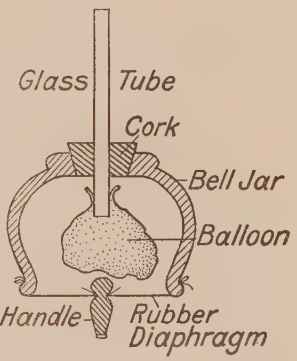

Fig. 44. — Apparatus to illustrate breathing movements and their effect upon the lungs. The rubber diaphragm corresponds to the diaphragm in the body; the handle to the tendon; the balloon to the lungs; the tube to the trachea; the bell jar to the walls of the thorax. As the handle is lowered the air flows down the tube and inflates the balloon.

Now move the handle downward so as to stretch the diaphragm. What happens to the balloon? What causes this action? Move the handle upward. What happens to the balloon now? Why? How does the diaphragm secure rhythmic inhaling and exhaling, *i.e.*, inflow and outflow of air?

LXV. — Study of Expired Air

Apparatus. — Chemical thermometer, limewater, test tube, glass tube, large-mouthed bottle, pneumatic trough.

Directions. — *A. Temperature.* Breathe on the bulb of the thermometer and determine the temperature of the expired air. Place the bulb under the tongue and determine the body temperature. How does the temperature of the expired air compare with that of the body, or blood temperature? Test this on several successive days and note whether the temperature varies with the external temperature or is constant.

B. Composition. Breathe on a piece of glass. What collects on the surface? Does expired air contain more or less moisture than inspired air?

Fill the test tube half full of limewater and blow the breath gently through it by means of the glass tube. What change takes place in the limewater? What does this indicate? (See Ex. VIII.)

Fill the bottle with expired air by the method of Ex. II. Turn the bottle mouth upward and introduce a lighted match into it. Does the match continue to burn? What does this indicate? (Air expired in ordinary breathing has lost about one-fourth of the oxygen contained in the air inspired.)

EXCRETION

LXVI. — Study of a Lamb's Kidney (Optional)

Apparatus. — A fresh lamb's kidney with its capsule of fat, scalpel.

Directions. — Carefully remove the outer layer of fat and the membranous inner capsule. What is the function of this material? (A dissection of the rat makes a good demonstration of the location of the kidneys and their relation to ureter and bladder.) Cut the kidney lengthwise so as to split the ureter where it emerges from the concave side. On the cut surface make out the pale inner striated *medulla* and its *pyramids of Malpighi*, the outer *cortex*, and the *intermediate layer* between the two. Note also the enlarged upper end, or *pelvis*, of the ureter; the cavity, or *sinus*, into which it opens; and the tubes, or *calices*, between the projecting pyramids. Note also the entrance of the renal artery into the kidney, and the renal vein, just above the ureter. From the accompanying Fig. 45 make out the parts which act in removing the waste. (The artery brings

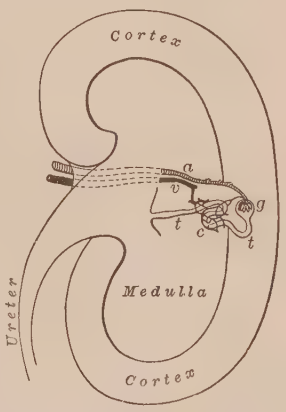

Fig. 45. — Diagram of a Longitudinal Section of a Kidney: *a*, renal artery; *c*, capillaries; *g*, glomerulus; *t*, uriniferous tubule; *v*, renal vein.

in the blood, which gives up its waste in the glomerulus. This waste is collected by the tubule and emptied by it into the ureter. The capillaries collect the blood which has been cleared of its waste, and return it to the vein.)

NOTE. — Prepared sections of injected and stained cortex may be shown and the following parts demonstrated: Malpighian bodies, uriniferous tubules and capillaries.

LXVII. — STUDY OF THE SKIN

Apparatus. — Prepared slide of epidermis (that from the sole of the foot preferred, from its thickness), a vertical section of a hair, compound microscope, needle, scissors.

Directions. — *A. Surface Study of the Skin Layers.* Sterilize a needle by holding it in a flame for a moment. Run it carefully under the thin outer layer of skin at the base of the thumb. (This layer is called the *cuticle* or *epidermis*.) Does the wound cause any pain? Are there any nerves in this layer? Does the wound bleed? Does the epidermis contain any blood vessels? With the needle tear off a little of this epidermis. What is its color? consistency? Where is it thickest on the hand? Why? Where else on the body do you find similar thickening?

What is the color of the skin layer (*dermis*) under this epidermis? Prick it with the needle. Is it sensitive? Does it contain blood vessels? Examine its surface and note that it is ridged. A magnifier will show that these ridges are made up of a series of points, or *papillæ*. (Each papilla marks the end of a nerve of touch. These nerve endings are called on that account *tactile organs;* see Fig. 46.) Pick up a little of the skin between the fingers. Is it attached to the underlying muscles? About how thick is it on the back of the hand? on the base of the thumb?

B. Microscopic Study of a Section. Study the prepared slide, under the high power. Note the layer character of the epidermis, the papillæ with their blood vessels, the coiled *sweat glands* and their ducts (thick sections show these best). Sketch and label all parts of your drawing as in the diagram.

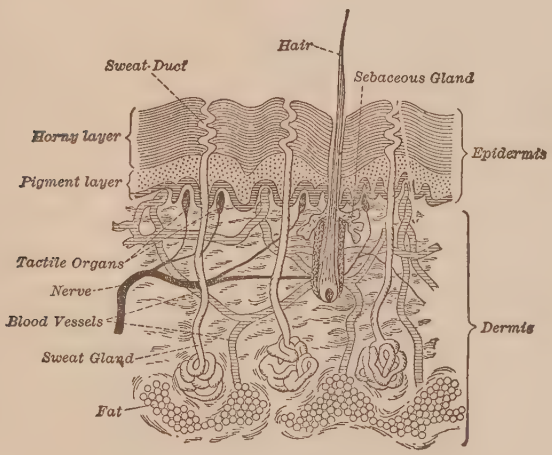

FIG. 46. — Diagram of Skin Section.

Compare the action of the sweat glands with that of the tubuli uriniferæ (uriniferous tubules) of the cortex of the kidneys. When do we perspire most? Why does exercise increase the amount? What is one function of the skin?

C. Study of Skin Modifications. (*a*) Hairs. Note the location of hair on the head. What is its function? Examine one of the hairs on the back of the hand. Cut it.

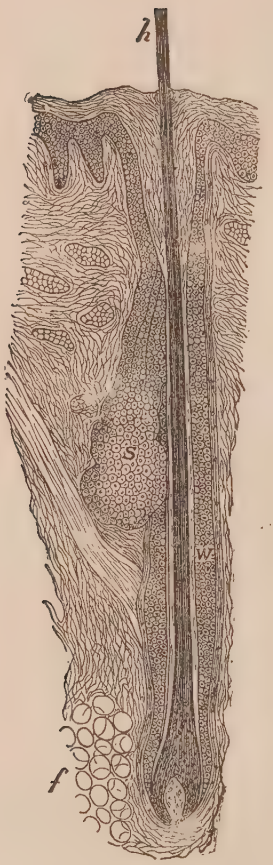

FIG. 47. — Hair-follicle in Longitudinal Section: *h*, hair shaft, showing its medulla or core; *s*, sebaceous gland; *w*, sheath of skin; *f*, fatty tissue. (At the base of the hair is seen the papilla that forms it.)

Is it sensitive? Pull it. Where is the sensitive portion located? Where is the seat of growth? What part of the skin is it most like?

Study the slide showing a vertical section of a hair under the low power of the microscope. Note that the hair is imbedded at the base in a skin *follicle*, and grows from a skin *papilla* at the bottom of this follicle. Note also the *sebaceous* or *oil glands* that serve to coat the hair with oil.

(*b*) Nails. Make a drawing of your finger nail, showing all areas. What parts are attached to the skin? Why is the part under the nail called the "quick"? What is one function of the nail? Cut it. Is it sensitive? Pull it. Where is its sensitive part located? How does it compare with the hair in this respect? Cut a nick in it and examine it from day to day. Does it change position? Where does the growth of the nail occur?

Tabulate all the functions of hairs, nails, and skin that you have learned.

NERVOUS SYSTEM

LXVIII. — Dissection of Sheep's Brain

Apparatus. — Sheep's head, bone forceps, hammer, scalpel, needle, forceps, 50 % alcohol.

Directions. — *A. To Remove Brain from Skull.* Strike the top of the skull with the hammer so as to crack the bone, but not to force it into the brain, and then carefully remove the pieces with the bone forceps. Be careful not to injure the underlying membrane (*dura mater*) which lines the skull and covers the brain. After the top of the skull is removed slit this dura mater around the edge, and remove it, exposing the brain. Note that over the surface of the brain is another membrane, the *pia mater*. Now carefully lift the brain from the floor of the skull, beginning at the front. Notice that it is bound by nerves and portions of the dura mater. Cut these nerves, leaving as long ends as possible, and do not cut off the olfactory lobes which are on the under side

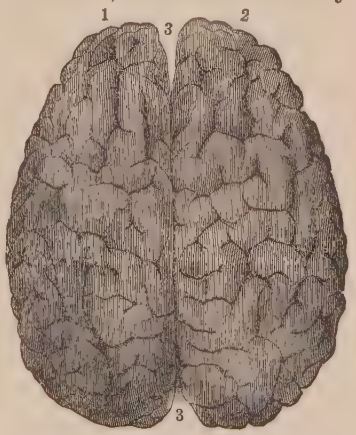

Fig. 48. — Upper Surface of Brain (Human): 1, 2, two halves, or hemispheres, of cerebrum; 3, 3, longitudinal fissure.

of the brain. Place the brain in 50 % alcohol to harden, for several days.[1]

B. The Coverings of the Brain. Tear off a little of the dura mater with the forceps. Does it tear easily? Are both sides of it smooth? Where are its blood vessels? What do they feed?

Pick up a little of the pia mater (brain cover) with the needle point. Is it thicker or thinner than the dura mater? Where are its blood vessels? What do they feed? What are the functions of the three coverings of the brain?

C. The External Parts of the Brain. Examine the top of the brain. Note the two convoluted hemispheres into which the fore brain (*cerebrum*) is divided by a fissure (the *longitudinal fissure*). Back of this appears the wrinkled surface of the hind brain (*cerebellum*). Is this divided?

Turn the brain over and examine the lower surface. Note the *olfactory lobes* on the front part of the hemispheres. What is their function? Back of these locate the *optic nerves*, and note how they cross to form a *chiasma*, so that the right eye is controlled by the left hemisphere, and vice versa. Just back of this may be seen the *pons*, or bridge, that connects the two sides of the cerebellum, and, coming out in front of it on each side, the stalks (*crura cerebri*), which spread out into the two hemispheres of the cerebrum. Note that the stalks are the forward projections of a conical spinal bulb which comes between the cerebellum and the pons and is continued backward into the spinal cord. This bulb is a part of the hind brain, and is called the *medulla*. All along the under side of the brain are located the cranial nerves, occurring in pairs. Beginning at the front, locate the pairs named in the following table:

[1] Preserve the skull, with eyes, for use in Ex. LXXV.

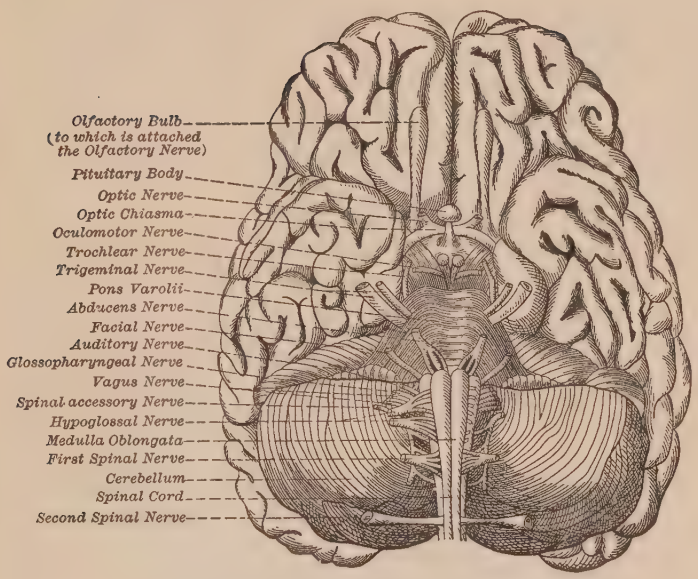

FIG. 49. — Under Surface of Brain (Human).

	NAME	FUNCTION
1st pair	Olfactory	Smell — Sensory
2d pair	Optic	Sight — Sensory
3d pair	Oculomotor	Eye Muscles — Motor
4th pair	Trochlear	Eye Muscles — Motor
5th pair	Trigeminal	Facial — Sensory and Motor
6th pair	Abducens	Eye Muscles — Motor
7th pair	Facial	Motor, mainly
8th pair	Auditory	Hearing — Sensory
9th pair	Glossopharyngeal	Tongue and Throat — Sensory and Motor
10th pair	Vagus	Thorax and Abdomen — Sensory and Motor
11th pair	Spinal Accessory	Motor
12th pair	Hypoglossal	Tongue — Motor

D. Vertical Section (*right side*). Cut the brain through lengthwise, parallel to the line of the longitudinal fissure, but one-sixteenth of an inch to the left of this line in order not to cut the septum. Examine the right side. Note the

white, fibrous body (*corpus callosum*) which unites the two hemispheres. In the front part of this are seen the thin membranes (*septum lucidum*) which inclose between them

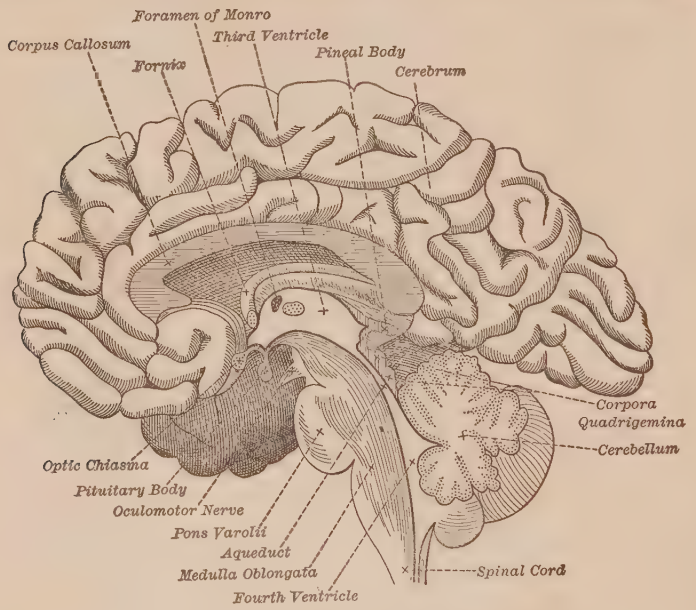

FIG. 50. — Section of Brain.

a portion actually outside the brain, but often called the "fifth" ventricle. Below this is the *fornix*, which forms the roof of a true brain cavity — the *third ventricle* — whose sides are the *optic thalami*. This ventricle projects forward into a funnel called the *infundibulum*. In the center of this ventricle is a round body (the *median commissure*) which was cut through by the section. In front of this is a small aperture (the *foramen of Monro*) that connects this cavity with a cavity in the right hemisphere. The floor of the third

ventricle is formed by the crura cerebri, which extend backward, between the pons and the cerebellum, into the spinal bulb or medulla, and this, in turn, backward into the spinal cord. At the back of the third ventricle note that a tube or canal (*aqueduct*) connects it with a much smaller cavity (the *fourth ventricle*) just under the cerebellum. Four little bodies (the *corpora quadrigemina*) form the roof of this tube between the fornix and the cerebellum. Note the tree-like internal structure of the cerebellum. What causes its wrinkled surface?

Note the gray and the white matter that make up the cerebrum. Where is the gray matter located? the white?

Note. — The first ventricle in the olfactory lobes and the lateral ventricle may be shown by suitable sections, if desired, and the relation of these may be brought out by the aid of diagrams of a simple brain structure.

LXIX. — Dissection of Spinal Cord

Apparatus. — Thin section of cervical portion of spinal cord, glycerine, slides, cover glass, compound microscope.

Directions. — (Prepare sections by placing a piece of the cervical spinal cord for three or four weeks in Müller's fluid [$2\frac{1}{3}$ parts of potassium bichromate, 1 part of sodium sulphate, 100 parts of water]. Then wash it with water and place it in 30 % alcohol for a few days. Then transfer it to 95 % alcohol. Cut a thin cross section and mount it in glycerine. Cover it with a cover glass).

Examine under the low power. Note the outer covering of *pia mater*. Note the distribution of the gray and white matter. Sketch it. Is it the same as in the brain? Note the division into two parts by a deep anterior, and a shallow posterior fissure. Note also two fissures in each half (an-

terior and posterior lateral) through which the central gray mass reaches the surface. The gray masses in each half of the cord may be seen to be united by a commissure that incloses the central or neural canal. Note the cellular character of the gray matter. The gray matter that forms the

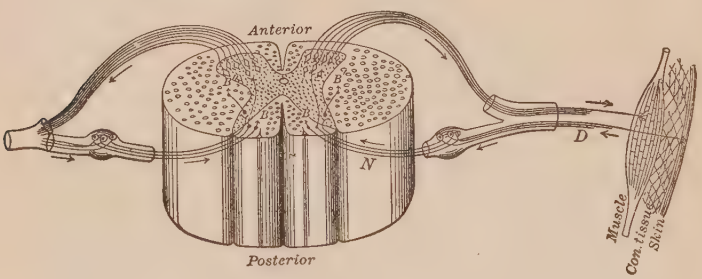

FIG. 51.

posterior horns forms the core of spinal nerves of the sort called *afferent*. The anterior horns form the core of *efferent* nerves. (Afferent nerves carry messages to the cord; efferent, away from it.) The white matter covers these and they unite outside in a common spinal nerve. (See Fig. 51.) For structure of a neuron, see Ex. XXXI.

SPECIAL SENSES

LXX. — Nerve Action

Apparatus. — A stop watch, pencil, paper.

Directions. — Let the teacher write a vowel on a piece of paper which he shall keep covered. Arrange the class in a circle. Station a boy beside the teacher with a stop watch. Proceed as follows: The teacher shows the vowel to the pupil on his right, who whispers it to the pupil on his right as quickly as possible, and so on around the circle to the teacher again. All this as rapidly as possible. Let the boy with the watch release the stop at the second when the teacher exposes the letter to the pupil on his right, and stop it again when the last pupil repeats the letter to the teacher. Divide the time elapsed by the number of pupils. The result will represent the average reaction time of each pupil. Change the arrangement of the pupils and note whether the time varies. What muscular action does each pupil perform in receiving and transmitting the sound? What sensory nerves are employed? what motor nerves?

Note. — In order to bring out various sensation reactions this experiment may be varied in many ways which will suggest themselves to the teacher.

LXXI. — Cutaneous Sensations

Apparatus. — A pair of metal compasses, toothpicks, a dish of boiling water, a dish of ice water, pen and ink.

Directions. — One pupil should operate, while another acts as subject. The subject should be blindfolded.

A. Touch. Sharpen the ends of the toothpicks and tie one to each arm of the compass. What is the least distance apart at which the two points may be held and felt as two points, when applied to the tips of the fingers? the tip of the tongue? back of the hand? forearm? back of the neck? Record the results. Are all parts of the body equally sensitive to touch? Which parts are most sensitive?

B. Temperature. Dip a metal point of the compasses in cold water and move it lightly over the back of the hand. Does it feel equally cold to all parts of the skin? Mark with an ink dot those points where the sensation is most acute. Now heat the metal point in the hot water and move it over the same area. Locate, as before, the spots where sensation is most acute. Do the hot and cold spots coincide? What do you conclude about the temperature sensation power of the skin? Is it a general or a localized sensitive power? Test other areas of the body in the same way. Are the temperature spots equally numerous in all parts? Where are they most numerous? least numerous?

LXXII. — Study of the Tongue

Directions. — Protrude the tongue as far as possible and with the aid of a mirror examine its surface. Note the raised points (the *papillæ*) on the surface. Observe that they are of three forms: long and slender (*filiform*), mushroom-topped (*fungiform*), and large and wartlike (*circumvallate*). Draw an outline of the tongue and locate on it the regions where these different forms are to be found.

LXXIII. — Sensations of Taste and Smell

Apparatus. — Onion, sugar, salt, vinegar, dilute ammonia, quinine, vanilla or other flavor.

Directions. — *A. Location of Taste.* Wipe the tongue and place on its tip a little dry sugar. Has it any taste? Let it dissolve. Has it any taste now? Repeat, placing the sugar at the back of the tongue. Is its sweetness more or less prominent? Repeat again, using quinine, vinegar, and salt successively. Where are the sensations of bitterness, sourness, and saltiness most prominent?

B. Taste and Odor. Examine the various substances named under "Apparatus." Which have taste? odor? Place each of these substances on the tongue of a pupil who has been previously blindfolded, and who is holding his nose tightly. Record the substances recognized by taste alone. Repeat, leaving the nose free but retaining the blindfold. Record those substances recognized by smell alone; by taste and smell combined.

LXXIV. — Hearing; Laws of Sound (Optional)

Apparatus. — Stretched wire, bridge to shorten length.

Directions. — *A.* Strike the wire. Do you get any sound? What is the wire doing? All sound depends upon vibration: test several sounding bodies to verify this statement.

B. Move the bridge to the middle point of the wire and strike again. Is the pitch higher or lower? Does a short string vibrate faster or slower than a long one? What effect has rate of vibration on the pitch of a sound?

C. Strike the wire gently. Note the distance at which the sound can be heard. Strike harder. Is the tone louder

or softer? Can it be heard at a farther distance? Does it vary in pitch? What effect on sound does extent (amplitude) of vibration have?

D. Stand at the point where you can just hear the ticking of a watch. Now make a conical tube of paper and insert the small end in the ear. Point the larger end toward the watch. Can you hear it any better now? What part of the ear serves a purpose similar to that of the tube?

E. Sympathetic Vibrations. Tune two wires to the same pitch. Place a paper rider on one and strike the other. What happens to the rider? Lower the pitch of one wire and repeat. Is the result the same?

LXXV. — Vision; Dissection of Sheep's Eye

Apparatus. — Sheep's skull with eyes in socket (the skull used in Ex. LXVIII will serve for this purpose), scalpel, scissors, bone forceps, evaporating dish.

Directions. — Cut away, with the bone forceps, the bones that inclose the eye, so that it may be seen in position from the side.

A. Muscles. Notice that the motion of the eyeball is controlled by six muscular bands. Locate the attachment of four of these bands on the top (*superior rectus*), bottom (*inferior rectus*), side near nose (*internal rectus*), and side farthest from nose (*external rectus*). Note that these extend directly backward to the end of the socket and have their origin there. What motions do these muscles give to the eyeball? Now locate on the top of the eyeball the attachment of a transverse band of muscle (the *superior oblique*) and follow its course, through a tendon pulley, to its origin at the back of the socket. In what direction does its contraction take place? What motion does it give

to the eye? On the under side of the eye locate another transverse muscle (the *inferior oblique*). Where is its origin? Has it a pulley?

B. The Externals of the Eye. Cut the muscle bands and trim away a white membrane (the *conjunctiva*, a continuation of the lining of the eyelid) in the front of the eye. Note that the eye is still attached to the socket by a cord, just below and outside the center of its rear surface. This is the *optic nerve*, which enters the eye here from the brain. Pull the eye out of the socket and cut this cord. Now examine the outside of the eyeball. Note that it is covered with a firm white coat (the *sclerotic*) except in the front, where there is a clear layer, the *cornea*, usually dulled in death.

C. The Internals of the Eye. Hold the eye with the cornea uppermost, and remove this with the scalpel by cutting horizontally around its edge. The liquid back of this layer is the *aqueous humor*. Directly back of the cornea appears a circular muscular curtain — colored in the human eye — called the *iris*, and in its center a hole — the *pupil*. What conclusions do you draw as to the functions of this iris from comparing the size of the pupil of your own eye, when looking at a bright light, with its size when in a dimly lighted room? Is its action voluntary?

Now lay the eye upon its side in the evaporating dish and cover it with water. With the scalpel cut a section through the entire eye, splitting the optic nerve (see Fig. 52). Observe the following parts: just back of the iris the convex *crystalline lens* and its capsule; the muscles that control the shape of the lens — the *ciliary muscles* — and their ligamentous attachment (*suspensory ligament*); on the inside of the layers that form the walls of the eye, at the edge of the lens, a black, ridged membrane (the *ciliary process*);

the jellylike mass that fills the body of the eye (*vitreous humor*); the three layers of the wall of the eyeball, — outer (*sclerotic*), middle (*choroid*), inner (*retina*).

Note that the optic nerve pierces the two outer coats and spreads out to form the retina. Remove the vitreous humor and notice the soft, whitish retina. Tear this out

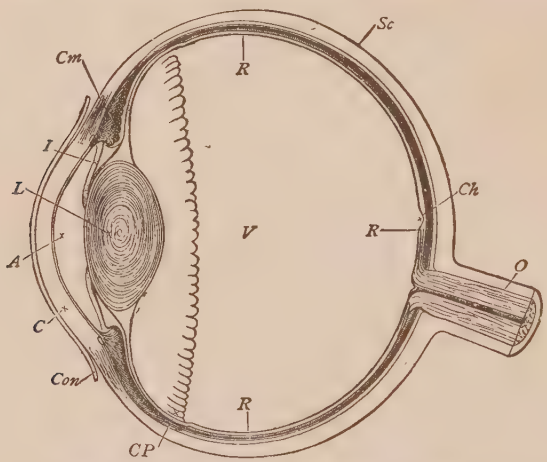

FIG. 52. — Cross Section of the Eye: *Con*, conjunctiva; *Sc*, sclerotic; *C*, cornea; *A*, aqueous humor; *I*, iris; *L*, crystalline lens; *Cm*, ciliary muscles and ligament; *CP*, ciliary process; *V*, vitreous humor; *Ch*, choroid; *R*, retina; *O*, optic nerve.

with the forceps and note its consistency and thickness. Under this observe the color and luster of the choroid coat. When this is torn out, the interlacing blood vessels are seen passing from one layer to the other.

LXXVI. — ACTION OF THE EYE

Apparatus. — Model of eye.

Directions. — Construct a model of the eye as follows: Obtain a wooden box eighteen or twenty inches long and

about eight inches wide and deep. Leaving one side open, paint the inside of the box black. Around the open side tack a piece of black cloth large enough to cover the head of the observer and shut out the light from the interior of the box. At one end of the box cut a hole one inch in diameter. Cut several black cardboard disks to fit this aperture, and perforate the center of each with holes varying from one-sixteenth to one-half inch in diameter. Mount a convex lens in a movable holder which can be moved forward and backward on the floor of the box, and which will bring the center of the lens opposite the center of the hole.

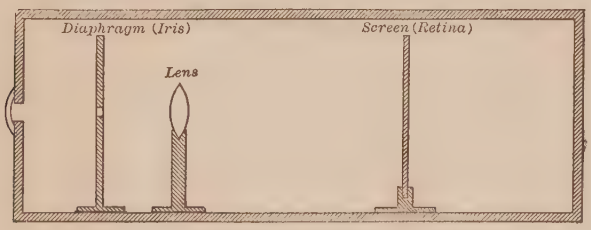

Fig. 53.

Mount a piece of ground glass in the same way to serve as a screen. Arrange all parts as in Fig. 53.

The cardboard disks will then correspond to the iris with its pupil; the walls of the box to the sclerotic; the black paint to the choroid (what is its function?); the lens to the crystalline lens, and the screen to the retina. A watch glass placed on the aperture would resemble the cornea.

A. Action of Parts. Darken the room and place a lighted candle at a distance of three feet from the aperture. Place in the aperture the disk with one-quarter inch perforation. Cover head with cloth and place screen at the rear of the box. Now move the lens back and forth until there ap-

pears on the screen a sharp image of the candle flame. Is it right side up? What is the function of the lens? Mark position of lens and screen. Move the candle three feet farther away. Does the image remain on the screen? Keeping the lens fixed, move the screen forward in the box until the distinct image appears again. Return the screen to its original position and, by moving the lens, cause the same result — an image on the screen. Which is adjustable in the eye — the screen (retina) or lens? How is the lens adjusted in the eye? (This adjustment of the lens to the distance of objects is called *accommodation.*) Change the disks in the aperture, using first larger and then smaller openings. Which gives the brightest image? What is the function of the iris?

NOTE. — By using external lenses as "spectacles," shortsightedness and longsightedness can be corrected and illustrated.

BACTERIA

LXXVII. — Study of Bacteria

Apparatus.— Culture medium (agar, 5 g.;[1] Liebig beef extract, 5 g.; Peptone, 5 g.; salt, 5 g.; water, 500 c.c.),[2] sterilized Petri dishes and test tubes, compound microscope, microscope slides, cover glasses, prepared slides of coccus, bacillus, spirillum, etc., forms, needle points, gentian violet stain, litmus paper.

Directions. — *A. To Demonstrate the Presence of Bacteria in Air.* Take two Petri dishes containing cooled culture medium. Examine, and note the transparent character of the medium. Now remove the cover of one of the dishes and allow it to remain exposed to the air of the room for ten minutes. At the end of that time recover it and set aside in a temperature of 36° C. Keep the cover on the second dish (control) and set it aside with the first dish. (N.B. Other dishes prepared in the same way may be exposed in various places to give variety and comparative results.) Examine these dishes from day to day until spots appear on their surface. Describe the color and appearance of these

[1] Agar makes a firmer jelly and is better for general use. In case it is not available gelatin may be used. In that case take 50 g. of gelatin.

[2] First dissolve in water all the ingredients except the agar and neutralize with sodium carbonate if necessary. Next dissolve the agar in boiling water and add, with stirring, the first solution. Neutralize again with sodium carbonate if necessary. Make up to 500 c.c. with water, boil and filter hot through absorbent cotton. Pour this hot liquid into sterilized Petri dishes and test tubes as desired. Cover the dishes and plug the ends of the test tubes with sterilized absorbent cotton.

spots. Then with the needle point remove some of the spots to a slide, cover with a glass, run a little water under the glass, and examine under the high power of the compound microscope. Describe with drawings what you see. Smear a little of one of the spots on a cover glass and pass the glass through a gas flame two or three times until dry. Mount the glass, smear side down, on a microscope slide. Run a little gentian violet under the cover glass and after a few minutes examine again. What effect has the stain?[1]

Do spots appear on the control dish? What does this prove as to the origin of the bacteria? Are the bacteria all alike in size and shape? Do all or any of them move? Are the spots all alike in color and shape? Examine several as above and report your results with drawings of the forms observed.

Write a detailed statement telling what you have learned about bacteria from this experiment.

B. To Demonstrate the Presence of Bacteria in Water. Take two test tubes containing culture medium. Pour into one 10 c.c. of ordinary drinking water and plug with sterilized cotton. Boil some water and pour 10 c.c. into the second tube. Plug in same way as first. Place both tubes at 36° C. and let stand several days. At the end of that time examine both tubes. Describe the difference in appearance, odor, reaction to litmus. Examine a drop of the water from each on a microscope slide. Record the results with drawings. Why does boiling water prevent infection?

C. To Demonstrate the Forms of Bacteria. Examine prepared slides of various types of bacteria and make drawings of same.

D. Variations of the Above Experiments.

[1] Bacteria do not stain readily until killed by heat or other means.

(*a*) Conditions favorable and unfavorable to growth may be determined by modifications of *B*.

(*b*) Protection from dust may be shown as a modification of *A*.

(*c*) Other substances may be substituted for water in *B*.

(*d*) The preparation of pure cultures may be shown by transferring to new dishes the colonies obtained in *A*.

(*e*) Examination for disease germs may be demonstrated by transferring mucus from throat, dirt from finger nails, blood, etc., to prepared dishes and examining the results as described in *A* and *B*.

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